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COTTONWOOD IN THE MISSISSIPPI VALLEY.

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Forest Examiner.

IMPORTANCE OF COTTONWOOD.

Cottonwood is one of the important timber trees native to this country. Twenty years ago it had almost no value; to-day its wood is extensively used and the demand for it is much in excess of the supply. It is a tree of very rapid growth. On rich lands yields of from 4 to 5 cords of wood per acre per year are not uncommon. Yields of over 30,000 feet of merchantable timber can be obtained in 40 years, and 20 years is sufficient to produce timber of fair dimensions. Cottonwood is especially valuable in the Mississippi Valley region, where it offers exceptional inducements for the conservative handling of timberlands in which it occurs, or for forest planting.

Cottonwood's importance as a tree for artificial forestation is attested by the fact that it has claimed the attention of forest planters in many foreign countries, such as France, Germany, Belgium, and Argentina. (See Pl. VI, fig. 1.) By careful selection certain French horticulturists have developed from this species improved varieties which are said even to exceed the original form in rapidity of growth. In South America, at the mouth of the Parana River in Argentina, a very extensive and lucrative industry has been developed by growing cottonwood on land subject to frequent inundations. (See Pl. II.) These plantations furnish saw timber from 10 to 12 inches in diameter. On account of the scarcity of timber there, boards but 3 or 4 inches wide and 6 feet long find a ready market at high prices. Such plantations pay as high as 15 per cent on the money invested.

In this country the possibility of growing cottonwood commercially, either by planting or by favoring it in natural stands, has not yet received the attention it deserves. Though cottonwood plantations as a source of future supply of pulpwood justify consideration, the tree's chief value will lie in the production of fuel and farm timbers, and for windbreaks, for which it has been extensively planted by farmers in the Middle West. (See Pl. VI, fig. 2.)

A special study has been made of cottonwood by the Forest Service, to determine more definitely its characteristics and the general practicability of forest management. The investigations were confined largely to the Mississippi Valley region, where cottonwood is commercially important. The conclusions reached in this bulletin, therefore, apply chiefly to this region, and more particularly to the southern part of the valley. The conclusions in regard to planting, however, apply wherever cottonwood can be grown.

ANNUAL CUT AND PRESENT SUPPLY.

The lumber cut of cottonwood for 1911 approximated 198,630,000 board feet. In addition a considerable amount of cottonwood was used for other purposes. Slightly over 25,000 cords, or 14,000,000 board feet, were used in 1911 for pulpwood, much of which, however, probably came from the black cottonwood. The veneer industry consumed another 35,000,000 feet, and over half as much more is reported to have gone into slack cooperage, while nearly 62,000 cords were used for excelsior. The total cut, therefore, was somewhat over 300,000,000 feet, board measure, exclusive of firewood.

As compared with important timber trees the cut of cottonwood is small, yet considering its limited commercial range and its restricted local occurrence it must be regarded as a tree of considerable commercial importance. The demand for its lumber is, in fact, in excess of the supply, as reflected by the rise in its mill-run value from $10.37 in 1899 to $18.12 in 1911. The value of the total cut of cottonwood for 1909, the last year for which values of products were obtained by the Bureau of the Census, was over $6,000,000, of which the lumber cut represented $4,794,424. Table 1 shows the cottonwood lumber cut for 1911, together with the estimated average value f. o. b. at the mill, arranged by States.

TABLE 1.—*Amount and value of cottonwood lumber cut in 1911.*

State.	Number of active mills reporting.	Quantity.		Value.	
		Thousand board feet.	Per cent.	Total.	Average per thousand feet.
Total	1,950	198,629	100.0	$3,599,157	$18.12
Arkansas	80	52,457	26.4	967,307	18.44
Louisiana	41	48,037	24.2	900,694	18.75
Mississippi	51	32,687	16.5	659,624	20.18
Missouri	265	11,545	5.8	188,876	16.36
Tennessee	55	8,308	4.2	129,854	15.63
Iowa	130	5,452	2.7	106,532	19.54
Wisconsin	63	4,339	2.2	62,178	14.33
Michigan	147	3,713	1.9	54,952	14.80
Minnesota	72	3,082	1.6	42,008	13.63
Washington	8	3,056	1.5	53,025	17.35
Maine	64	2,620	1.3	37,833	14.44
Ohio	154	2,288	1.2	41,527	18.15
Texas	11	2,248	1.1	39,902	17.75
Alabama	16	2,015	1.0	25,691	12.75
All other States	793	16,782	8.4	289,154	17.23

Cottonwood is so widely and irregularly distributed that an estimate of the amount of standing timber would be almost impossible to obtain. Its commercial range is confined principally to the bottom lands of the Mississippi River and similar situations for some distance up many of its tributaries, especially the Missouri, Ohio, Arkansas, St. Francis, Yazoo, and Red Rivers. Probably the largest supply of valuable cottonwood timber is in the States of Arkansas, Louisiana, Mississippi, and Missouri. It is also common in the northern Mississippi Valley, especially Minnesota, Iowa, Illinois, and Indiana, but in this region it attains far less importance than in the South. A large proportion of the cut reported from these States probably comes from planted groves. In the remainder of its range it occurs too scatteringly to warrant extensive lumbering operations.

Although no estimate is available, there is every indication that the supply is failing. The output of cottonwood lumber fell off 52 per cent between the years 1899 and 1911. The State of Arkansas, which still leads in the production of cottonwood lumber, manufactured less than one-half as much in 1911 as in 1899. In all probability the maximum cut of this species has long since been passed.

CHARACTER OF THE WOOD.

The wood, although relatively not strong, is strong in proportion to its weight. It is tough, and extremely light when well dried, a cubic foot weighing about 24.25 pounds, or nearly the same as white pine. Its specific gravity is 0.3889 (Sargent). The fuel value is 51 per cent of that of white oak, and the amount of ash is 0.96 per cent of the dry weight of the wood (Sargent). The modulus of rupture, which is an index of breaking strength, is 84 per cent, while the modulus of elasticity, which is an index of stiffness, is 67 per cent of that of white oak.

The wood has a close, even texture, is quite porous, and only moderately hard. It displays numerous although obscure medullary rays. Because of its tendency to warp, it requires care in seasoning, unless properly piled. The heartwood is glossy light brown in color. The sapwood, which seldom is more than 2 or 3 inches thick, is creamy white. When seasoned the wood is almost tasteless and odorless. As a rule it is easily worked and finished, but occasionally trees seem to produce a tougher fiber which tears badly in sawing and planing, producing a "brashy" or "woolly" surface. Lumber of this character is often termed "white" cottonwood, in distinction from the yellow.

These two kinds of wood are thought by some lumbermen to come from distinct species. Woodsmen often claim that they can tell

the difference in the tree—pointing out that the "white cottonwood" has a closer, thinner bark of darker color than the thick, rough, grayish bark of the "yellow cottonwood." There seems to be no doubt, however, that both the white and the yellow varieties come from the same species.

The yellow cottonwood is not only darker in color, but is said to work more easily and be less subject to warping. It is probably the wood of the older trees. The white cottonwood appears to come usually from comparatively young trees of rapid growth, which, however, may be as large as older, slower-growing individuals. Yet white cottonwood lumber is by no means typical of the younger stands, which usually saw out wood of excellent quality.

USES.

Cottonwood has a wide range of uses, and for certain purposes is being used in place of much more costly woods, such as white pine and yellow poplar. It was for a time marketed as "sap poplar," but was soon accepted by the wood-using industries under its true name.

In the manufacture of shipping cases for food products cottonwood is used in large quantities. When properly seasoned it imparts little if any taste or odor to the contained product. For this reason also it is in demand for candy pails and the like. Its toughness and lightness give cottonwood additional fitness for boxes and crates. Experiments by the Forest Service[1] to determine the comparative strength of packing boxes of various woods demonstrated beyond question that, when taken weight for weight, the cottonwood box outclasses in strength similar containers of practically all other species extensively used—such as white pine, yellow pine, spruce, hemlock, and red gum. Bulk for bulk, cottonwood is surpassed only by red gum.

A large amount of cottonwood is manufactured into rotary veneer, which is employed for a wide variety of purposes, cores or filling of built-up lumber, panels, bottoms, sides and backs of drawers, lightweight veneer boxes, cases, egg crates, baskets, and trunks. Such veneer opens up a large field of uses for cottonwood from which it would otherwise be excluded because of its liability to warp. Three-ply veneer three-eighths of an inch thick is much stronger than solid wood five-eighths of an inch thick. Considerable cottonwood veneer, 3 to 5 ply, is exported to Europe for backing upon which to lay more costly woods in the manufacture of musical instruments, cases, and furniture.

Since cottonwood in close stands early clears itself of branches, select logs cut out a fairly high percentage of clear and upper grades

[1] Forest Service Circular 47, "Tests of Packing Boxes of Various Woods."

of lumber. Cottonwood is used but is not popular for flooring, partition, siding, and ceiling. When properly stained it makes a remarkably attractive wainscoting, door panel, balustrade, etc. When exposed to weather as siding it warps and decays unless painted. Cottonwood is extensively used for barn framing and roof boards, and is employed to some extent in freight cars and as bridge planking. Because of its clean, white, uniform surface, it is excellent for pyrography. It is used extensively by the manufacturers of slack cooperage for staves and heading.

Cottonwood has for some time been used in the manufacture of pulp. It is reduced usually by either the soda or the mechanical process, but also yields well to the sulphite method. Experiments by the Forest Service show that cottonwood makes a pulp almost identical in character with that from aspen, which is used more than any other wood for the production of soda pulp. At the present time cottonwood is used extensively on the Pacific coast for the production of "news" paper. Cottonwood ground pulp has a comparatively short fiber and must usually be mixed with about 60 per cent of long-fibered pulp, such as that of spruce, in order to make finished paper. The pulp produced by the soda and sulphite processes is used to some extent in the manufacture of book and magazine paper.

Cottonwood has also been used considerably for excelsior, for which it is highly prized. Although statistics are not available to show the quantity of fuel cut from this timber, it is undoubtedly large.

PRESERVATIVE TREATMENT.

One serious objection to cottonwood is its rapid decay when exposed to the weather or when in contact with the soil. To make the wood more durable, preservative treatment will in many cases be necessary. Because of its open, porous texture, cottonwood takes preservatives readily, the treatment requiring comparatively small expense.

Treated cottonwood fence posts have given excellent service. It is probable, therefore, that cottonwood can be grown to post size and the posts creosoted at less expense than much more durable species of slower growth which require no treatment. Creosoting tanks of the type described in Farmers' Bulletin 387, "The Preservative Treatment of Farm Timbers," can be easily constructed and will prove thoroughly effective in treating stakes, posts, or small poles for farm use.

Although tests are being made with treated cottonwood railroad ties, it seems doubtful if they will prove sufficiently strong for use under heavy traffic.

If properly treated, cottonwood should prove valuable for mine props, especially where only short or moderate lengths are required. The large proportion of the wood now wasted in tops and removed in thinnings could be used for this purpose.

Siding or rough lumber exposed to the weather can be made resistant to decay by the application of paint containing a large proportion of oil. The smooth, hard surface of the cottonwood board takes paint readily without absorbing a large quantity.

STUMPAGE VALUES AND LOGGING COSTS.

SAW TIMBER.

The greater and wider use of cottonwood has naturally resulted in a gradual and steady upward course of its stumpage value. Twenty-five years ago well-formed cottonwood trees standing almost at the edge of the river and often containing more than 2,000 or 3,000 board feet of high-grade lumber could be purchased for 50 cents a tree. Even more recently cottonwood could be obtained almost anywhere along the Mississippi River for 50 cents a thousand feet board measure on the stump, and logs were often delivered at the mill for $4 per thousand feet. In the early days the idea was generally prevalent that the cottonwood in the Mississippi Valley bottom lands was almost inexhaustible. Even to-day many stumpage owners are not aware of cottonwood's true value, and often sell merchantable cottonwood timber, accessibly situated, at extremely low prices.

It appears to be a general view among representative millmen in the lower Mississippi Valley that a stumpage price of $5 per thousand is none too high for average cottonwood timber accessibly situated near the river bank and requiring no longer hauls than from a quarter of a mile to a mile. Stumpage prices as high as $8 are reported as actually being paid for standing timber of the best quality when especially accessible.

The money value of timber on the stump, as of any other commodity, should be determined by the actual cost of producing it, plus a fair profit to the producer. In artificial plantations the true stumpage value can be readily determined. In virgin timber, which is a free gift of nature, the cost of production can not be determined, and the actual stumpage prices are controlled chiefly by demand and supply. Theoretically the stumpage value of virgin timber is the difference between the actual market value of the lumber and the cost of producing it. The latter figure should include not only the costs of logging and manufacturing, but also the operator's profit. In other words, if a lumber company must be assured of a profit of p per cent on all money invested in stumpage, logging, and manufacturing,

the stumpage value, S, could be expressed by the following formula, in which M represents the market value of the manufactured lumber at the mill, L the logging costs, and Mf the sawmill costs:

$$S = \frac{M}{1.0p} - (L + Mf)$$

From the data supplied by the principal cottonwood concerns the following lumbering costs per thousand board feet may be considered typical for the lower Mississippi region: Felling, 65 cents; hauling, $4 (for maximum of three-fourths mile); rafting, 85 cents (50 to 75 miles), or barging, $1 for average of 100 miles; which makes a total of approximately $5.50. Where the logging operation is within 25 to 30 miles of the mill and the timber comparatively close to the river, the total cost for logging and transportation may easily fall as low as $4. The cost of sawing is believed by many millmen to be at least $5 per thousand. Often, however, $4.50 will probably cover the mill end of the operation, including the interest on the investment, cost of upkeep, and all overhead charges. Under average conditions, therefore, the cost of manufactured lumber, f. o. b. at the mill, exclusive of stumpage and manufacturer's profit, should not exceed $10 per thousand board feet, and may be considerably less.

The market value for manufactured cottonwood lumber mill-run in Missouri, Arkansas, Tennessee, Louisiana, and Mississippi was, in 1909, $19.09 per thousand feet, f. o. b at the mill, varying in different States and at different seasons between $18 and $22. Boxboards practically clear of knots and from 13 to 17 inches wide sold during the same year for from $40 to $50, while wider boards of the same quality, termed panel stock, ran proportionally higher. The lowest grades quoted in the Forest Service Record of Wholesale Prices of Lumber, viz, No. 2 common, ranged from $12 to $15. These quotations, since they include no item for freight charges or selling costs, are, of course, considerably lower than the wholesale prices at the larger lumber markets, such as New York or Chicago.

Assuming $19 per thousand board feet as a typical f. o. b. mill value for the manufactured lumber, and logging and milling as $5.50 and $5, respectively, the formula works out as follows, where a profit of 20 per cent to the manufacturer is allowed:

$$S = \frac{M}{1.0p} - (L + Mf) = \frac{\$19.00}{1.20} - (\$5.50 + \$5.00) = \$5.33.$$

If several years are required to complete the logging operation, however, this formula should also include the interest on the money invested in stumpage, and the stumpage value in such an event would be found by deducting the interest at a fair borrowing rate, say 6 per

cent, for the average length of time invested. The equation then reduces to the form $S=\frac{\$5.33}{1.06^n}$, where n equals the number of years required for the operation. For a 2-year operation in the case considered $S=\frac{5.33}{1.06}=\$5.03$.

It is believed that this will represent a fair average for cottonwood in the southern part of the valley. In the river bottoms of the Northern States, such as Minnesota and Wisconsin, cottonwood yields wood of poor quality, and has a comparatively low value. Practically no grade corresponding to the wagon-box boards cut from the southern cottonwood is obtained. The best grades are usually put together and sold locally for heavy shipping cases, the manufacture of cheap furniture, or for the framework, roofing, and siding of farm buildings. Such lumber is sawed principally by portable mills and brings about $22 per thousand delivered to the consumer. The poorer grades, aggregating possibly one-third of the cut, are usually worth little more than $12 to $14 per thousand for the manufacture of packing boxes or crates, or for use about the farm. An average of $19 per thousand for mill-run delivered would probably be a representative price in this region. From this must be deducted the cost of transporting the lumber either by wagon, railroad, or both, to the point of delivery. A man and team at $4.50 per day should haul on good roads 1,000 feet per trip and load the lumber on the cars. Assuming a possible distance capacity for the team of 18 miles per day, the cost of hauling should not exceed $1.50, $2.25, and $3, respectively, for hauls of 3, 4½, and 6 miles, assuming an average day of 10 hours. Freight charges to be deducted will seldom be over 60 cents per thousand for the short shipments usually necessitated. Deducting $2.75 for hauling (4½ miles) and freight, the lumber at the mill should be worth $16.25. Where the mill is set up on the tract to be logged the total cost of delivering logs at the mill should not exceed $2 or $3 per thousand, which would allow one-quarter to one-half mile haul. Portable sawmills will usually saw cottonwood for from $4.50 to $5.50 per thousand. Since in this case the stumpage value itself represents the profit of the owner, the stumpage-value formula would here take the form $S=M-(L+Mf)$. By substituting in the formula what are considered to be representative values for this region, we get $S=16.25-(2.50+5.00)=\$8.75$. With no lumber haul, as when the mill is located on a railroad, the value per thousand would be the full $19 and lumber near the mill might easily be worth $10 or more on the stump. This higher stumpage value for cottonwood in the northern part of the valley, in spite of its poorer quality, is due partly to the lower logging cost from having the mill at the

source of supply, and partly to the better demand for what in the South would be classed as rather low grades.

The stumpage value of planted groves of cottonwood in the prairie regions, especially in southern Minnesota, Iowa, the Dakotas, Kansas, and Nebraska will necessarily be higher than in the natural stands outside this region. The general adaptability of cottonwood for barn framing, roofing, stable flooring, bridge planking, etc., gives it a ready sale at prices ranging from $20 to $22 per thousand mill-run. The cost of sawing, however, is also greater in this region, due to the limited amount of logs available at a given set-up and the few mills operating. It should, however, seldom exceed $7.50 per thousand. The cost of cutting and yarding the logs will, on the other hand, in some degree offset this increase, and should not exceed $1.50 per thousand. Since generally most of the lumber will be used by the owner himself or his neighbors, it should have a value at the mill of at least $21, with a correspondingly high stumpage value. In this case the formula works out:

$$S = 21 - (1.50 + 7.50) = \$12.$$

In this region, therefore, we find the highest stumpage value prevailing anywhere, and in this figure no account is taken of the protective value of the groves for windbreak purposes.

CORDWOOD.

Considerable quantities of cottonwood are sold in the form of cordwood—principally as pulpwood stock and as stave and excelsior bolts. In determining the stumpage value of such material, the market value of the final product, whether pulpwood, stave, or excelsior, is not considered, for it would entail a very technical study of the costs of manufacture. Instead, the price generally offered for the cordwood delivered is taken as the value per thousand in the stumpage equation, from which is deducted the costs, L, of producing the delivered cordwood. The stave and excelsior companies usually pay about $6 per cord delivered. At present paper companies do not, as a rule, obtain cottonwood from the Mississippi region, but till recently purchased such material at prices that brought the total cost delivered at mills in Ohio and Indiana up to approximately $7 per cord. The woods operations are alike for these various products, except that excelsior stock and sometimes pulpwood stock must be peeled in the woods while green. The cost of felling and peeling and cutting into lengths is about $1.25 per cord. A haul of a fourth to a half mile to the river seldom exceeds $1 per cord. Barging is a variable cost, dependent upon the distance, but under average conditions should not exceed $2 per cord for 75 miles, including loading and unloading. If a profit of 20 per cent be allowed to the

operator or contractor, the stumpage value per cord for stave or excelsior bolts would be worked out as follows:

$$S = \frac{6}{1.20} - 4.25 = \$0.75$$

The costs of transportation either by barge or railroad or both to the paper mills in the North Central States is so great that it is doubtful if a much larger stumpage price than the above would be paid for peeled pulpwood in the Mississippi Valley between Cairo and Memphis. Such stock does not seem ever to have been bought farther south. As a matter of fact, when such stumpage has been bought, it has seldom been considered worth more than 50 cents. On the other hand, if pulpwood should be grown on suitable land within 10 or 20 miles of the mill, and provided the delivered cordwood was worth $7.50 per cord to the company, the stumpage would be far more valuable. Under such conditions the cost of cutting, hauling, and shipping might easily be reduced to $4, giving the following results:

$$S = \frac{7.50}{1.20} - 4.00 = \$2.25$$

As a rule, however, a company in need of pulpwood stock would not require that the stumpage return a profit, and unless the operations took at least half a year probably no interest at all would be charged to the purchase of stumpage. If the company had grown its own trees the determination of the stumpage cost would include all necessary interest charges of this character, but the stumpage value would be merely the difference between the value of the wood delivered at the mill and the cost of cutting and transportation, together with any profit that might be demanded on such costs. The question as to whether or not the growing of the trees has resulted in profit or loss can not affect the actual stumpage value. If the latter is insufficient to cover the costs of growing the wood, the loss must be charged against the planting investment, not against the stumpage. Therefore, the formula should properly be—

$$S = M - (1.0pL) = \$7.50 - (1.20 \times 4.00) = \$2.70.$$

RANGE.

The common cottonwood, *Populus deltoides* Marsh, occurs principally along the margins of streams from the Province of Quebec and the shores of Lake Champlain down the Connecticut River and along the Atlantic coast south to northern Florida; and westward, except in the higher altitudes of the Appalachians, through the Mississippi Valley to the foothills of the Rocky Mountains in New Mexico; and northward into southern Alberta. East of the Appalachians it is very scattering and rare. It follows up the tributaries

of the Mississippi River into the Great Plains region, where it is found at altitudes as high as 9,000 feet, but is confined to the river banks.

BOTANICAL CHARACTERISTICS.

Populus deltoides Marsh is usually known merely as cottonwood, but in certain sections is variously spoken of as Carolina poplar, yellow cottonwood, white cottonwood, big cottonwood, cotton tree, broadleaved cottonwood, Vermont poplar, necklace poplar, and still other local names. It has been introduced into Europe, where it is variously termed the Swiss white poplar, the black Italian poplar, the Canadian poplar, etc.

The leaves, which are usually from 3 to 6 inches long and equally board, are more or less triangular in shape, sharply pointed, prominently veined, and edged with glandular incurved teeth. The leaves on the more vigorous shoots in the top of the tree are frequently more than twice the length of the others. When crushed they emit a pleasant balsamic odor. The leafstalks are flattened on the sides for most of their length, but become more round near their junction with the twig. Cottonwood has long, pointed, greenish or reddish-green winter buds, which are very resinous and are somewhat flattened. The bark on the younger stems and branches is comparatively thin and of a light grayish-yellow color, tinged with green, but on the trunks of older trees becomes rough, thick, and deeply furrowed and is dark grayish in color.

In cottonwood the male and female flowers are borne on different trees (dicœcious). Seed therefore is borne only on female individuals, whereas the male trees are always barren. The flowers bloom from February to April, according to the latitude, and always before the leaves are out. They occur in long pendulous catkins. The female catkins mature toward the last of April or May, even before the leaves have attained full growth, at which time the 3 or 4 valved capsules open and shed large quantities of "cottony" seed that is carried far and wide by the wind. To this abundant production of downy-coated seed cottonwood owes its name as well as the disfavor in which it is sometimes held for lawn and street planting. It is a very simple matter, however, to overcome this objection by propagating only male trees. (See fig. 1.)

Populus deltoides is easily distinguished from the swamp cottonwood (*Populus heterophylla* Linn.), which has somewhat the same range, by its distinctly triangular-shaped leaves and its thicker, more closely attached bark. In the western extension of its range cottonwood grows with norrow-leaved cottonwood (*P. angustifolia* James), which is readily disinguished by its narrow lanceolate leaves.

SILVICAL CHARACTERISTICS.

DEMANDS UPON SOIL AND MOISTURE.

Cottonwood requires abundant soil moisture. It is not adapted to dry situations, such as ordinary upland sites with thin soil. It

FIG. 1.—Catkins, twigs, and leaf and flower buds of cottonwood. *a*, Pistillate catkin; *b*, enlarged scale of staminate catkin; *c*, staminate catkins; *d*, twig with leaf-buds; *e*, twig with flower-buds; *f*, twig, showing angularity; *g*, longitudinal section of leaf-bud; *h*, longitudinal section of flower-bud.

seldom establishes itself naturally where surface moisture is lacking, although, if planted on such sites, it frequently makes very satis-

factory growth, provided the roots can readily penetrate to a moist subsoil. Moisture is especially essential for the germination of cottonwood seed. It is this characteristic which accounts for the occurrence of the species on sandbars and overflow lands along streams and the borders of swamps and lakes.

Cottonwood, however, is in no sense a swamp tree, in spite of a rather general impression to the contrary. True, it withstands extremely long periods of inundation by the spring floods of the Mississippi River and its tributaries. Yet such overflows are not comparable to standing swamp water, which is deficient in the free oxygen essential to root function. In the spring floods to which the cottonwood is subject there is a continual current of water about the base of the trees. After the recession of the floods the water table descends often many feet below the ground surface. The upper soil strata are then thoroughly drained either toward the river or toward the back sloughs. Cottonwood will not show thrifty development on very poorly drained situations.

The quality of the soil itself affects the local occurrence of cottonwood but little. With abundant moisture the tree appears to thrive on poor, sandy sites as well as on the stiffer clay soils. On typical overflow lands, however, the rich, alluvial deposits of comparatively close, fine texture seem to conserve the moisture better than the coarse, deep sands. The best growth of cottonwood therefore occurs as a general rule on the former sites. Yet if the water table is near the surface during the growing season, very well-developed stands are found on rather infertile sandy or gravelly soils.

LIGHT REQUIREMENTS.

Cottonwood is extremely exacting in its light requirements. Without doubt it is the most intolerant species in the Mississippi bottomlands. Young cottonwoods are seldom found coming up under a normally dense stand of older trees. Even under exceptionally favorable soil and moisture conditions the young growth seldom survives for longer than one summer. Direct overhead light alone is scarcely enough to encourage reproduction. This extreme intolerance of shade remains with the tree throughout its life and accounts for the rapid thinning out of pure cottonwood stands with age. The intolerance of cottonwood is also responsible for the ease with which the trees clear themselves of side branches in close stands.

Compared with the tolerant pine or spruce, cottonwood of the same age has fewer trees to the acre. Thus at 35 years, when the trees average 20 inches diameter breasthigh, an acre will bear only 50 to 75 trees. The amount of wood produced per acre, however, is as great, if not greater, in white pine or spruce stands.

As with all species, the demand of cottonwood upon light varies with the amount of moisture in the soil, and occasionally trees survive under shade, provided moisture conditions are exceptionally favorable.

SUSCEPTIBILITY TO INJURY.

WIND.

Cottonwood is fairly windfirm, but in exposed situations it is likely to suffer from breakage on account of the brittleness of its branches. Windfall is common only on rather wet, poorly drained sites, where the roots lie near the surface. In well-drained soils cottonwood sends a rather stocky taproot, well reenforced with spreading laterals, down to a depth of 4 to 6 feet.

FUNGI.

Damage from fungi is not serious in the Mississippi River Valley. On unfavorable sites, however, especially in plantations outside its natural habitat, injuries from this source are often more or less pronounced. Of the several diseases, the most common and injurious is the "rust," caused by a fungus (*Uredo melampson medusæ* Thüm.), which is said materially to check the growth of the tree. This and many other leaf fungi are likely to do considerable injury to young trees in the nursery. In such instances it is advisable to burn the diseased leaves at the end of the growing season. Spraying with Bordeaux mixture is often effective.

Of the fungi attacking the wood of cottonwood, *Fomes applanatus* (Pers.) Gill [1] (*Elvingia megaloma* (Lév.) Murrill), is one of the most noticeable, but seldom gains entrance to perfectly sound trees. It attacks both heartwood and sapwood, causing a white rot that weakens and sometimes kills the tree. Wounded and fire-scarred trees are most liable to such injury. Other fungi attack the twigs and branches of cottonwood. These include species of *Cytospora* and *Nectria*, which cause dead spots or cankers in the bark, resulting in the death of branches beyond the point affected. Very little is known of some of these fungi, but as a rule they seldom do serious damage in cottonwood stands, and expensive measures for combating them are rarely justified. The ordinary procedure in case of widespread fungous attacks is to cut out all diseased trees and burn or remove them.

The cottonwood in the southern United States is subject to damage by the mistletoe, *Phoradendron flavescens* (Pursh.) Nutt.[2] Injuries

[1] Heald, F. D. A disease of cottonwood due to *Elvingia megaloma*, Nebr. Agr. Expt. Sta. Rept., vol. 19, pp. 92–100, 1906.

[2] Bray, W. L. The mistletoe pest in the Southwest. Bureau of Plant Industry Bulletin 166, February, 1910.

from this source are especially pronounced in the Red River Valley region of Texas and Oklahoma. Although the apparent injury is confined to the branches, the vitality of the whole tree is weakened through loss of nourishment withdrawn by the parasite.

INSECTS.

Many species of insects attack cottonwood, but with few exceptions cause no serious damage to the trees. The exceptions are found in one or two species, the larvæ of which bore into the living bark and sapwood, sometimes doing serious damage. If any serious injury by insects is found, the matter should be reported to the Bureau of Entomology, Department of Agriculture, Washington, D. C. Specimens of the insects or of their work should accompany such a report.

ANIMALS.

The thin bark of young cottonwoods is relished by field mice and rabbits, and at times large numbers of trees are completely girdled by their gnawing. Girdling by mice is most likely to occur under snow or in deep grass. Rodents may destroy most of the young trees or cuttings in a cottonwood plantation, which makes planting on grassy sites a hazardous undertaking. Seedlings, however, usually sprout from the root collar below the injury. In the case of natural reproduction, where the trees come up so densely that the loss of 75 per cent or more during the first two or three years is of little consequence, the damage from this source is but slight.

Cattle are very fond of the green shoots and foliage of cottonwood and should be kept out of young growth, either natural or planted, for the first three or four years, after which they will do but little harm.

FIRE.

Cottonwood is very susceptible to fire injury while young, but by the time it is 15 to 20 years old has produced a fairly fire-resistant bark. Fires are, moreover, not likely to start or become serious on bottoms subject to overflow. Young cottonwood stands should be carefully protected against fire.

REPRODUCTION.

FROM SEED.

Cottonwood reproduces readily both by seed and by sprouts. Female trees bear seed in abundance practically every year. They begin to seed very early in life, probably when not over 10 years of

age, and continue to bear vigorously throughout most of their existence. The trees of the two sexes are usually unevenly distributed, and female trees may sometimes be greatly outnumbered by males. The seed matures, as a rule, during May or early June, when the capsules open.

The seeds are very minute, usually about an eighth of an inch long, and sometimes no more than one-twelfth of an inch wide. They are oblong, obovate, rounded at the apex, rather light brown in color, and are surrounded at the large end with a fringe of long, white, silky hairs which gives them a characteristic cottony appearance and renders them extremely light and buoyant. Seed dissemination, therefore, takes place easily, the seed often being carried by the wind miles from the parent tree. Seed dispersion is also effected by the overflow waters, which frequently leave fertile seed on the muddy alluvial deposits far from the parent tree.

The germinating power of freshly collected mature cottonwood seed is comparatively high, varying from 60 to 90 per cent. With proper moisture conditions the seed germinates very quickly. The vitality of the seeds, however, is very short-lived, few, if any, germinating when more than a month old. Seeds three weeks old have a germination of 50 per cent.

Cottonwood is fastidious with regard to a suitable germinating bed. Reproduction is almost entirely restricted to situations where the mineral soil is exposed, and even on such sites the seed demands abundant moisture. This explains why cottonwood seldom starts on any situations except moist, newly formed sandbars or abandoned cultivated fields.

Reproduction by seed in the Mississippi bottom lands is probably dependent to a considerable degree on the overflows which saturate the surface soil. Even on areas not inundated the water table may rise so near the surface as to supply the seed with sufficient moisture. Reproduction seems to be surest on situations which have been inundated, and every exceptionally high overflow is followed by a rank growth of young cottonwoods wherever the shade and ground cover will permit. It is probable that another benefit of this high water lies in the thin silt deposit left by the receding water, which affords an ideal germinating bed.

FROM SPROUTS.

Cottonwood reproduces also from sprouts, both from the stump and from the roots. Root sprouts, however, are comparatively infrequent and from the standpoint of management are of minor consequence. Stump sprouts originate both at the base of the stump and the root collar, and at the top of the stump from the cambium between the bark and the wood.

COTTONWOOD NEARLY 7 FEET IN DIAMETER, SHOWING THICK, DEEPLY FURROWED BARK, TYPICAL OF THE SPECIES.

EXTENSIVE COTTONWOOD PLANTATION NEAR BUENOS AIRES, SOUTH AMERICA.

There is an important relation between the height of the stump and the proportion of sprouts arising respectively from the root collar and the top of the stump.[1] Of the two kinds of sprouts, only the former is of practical importance from the standpoint of renewing a stand commercially. Sprouts from the top of the stump are dependent upon the stump for support, as they are unable at once to form an independent root system of their own. Cottonwood stumps, however, decay rapidly, and as the mechanical support of the new sprouts thus becomes weakened they are easily sloughed off and eventually are almost always thrown by the wind. The number of vigorous sprouts from the root collar decreases with the height of the stump; other conditions being favorable, very low stumps (below 6 inches) invariably produce vigorous sprouts. Very little dependence can be placed upon stumps more than 15 inches high to sprout vigorously from the root collar. In fact, stumps higher than 11 inches produce a disproportionately large number of sprouts from the top of the stump. If dependence is to be placed upon sprouts from the root collar, it would therefore seem advisable to cut the stumps as low as 6 inches, if possible, and certainly not higher than 12 to 14 inches. Table 2 shows the relation between the height of stump and the kind and vigor of sprouts.

TABLE 2.—*Relation between height of stump and kind and vigor of sprouts.*

Height of stump.	Number of stumps.	Average number of sprouts on root collar.	Average number of sprouts on top of stump.	Average number of vigorous sprouts on stump.	Average height of sprouts.	Height of stump.	Number of stumps.	Average number of sprouts on root collar.	Average number of sprouts on top of stump.	Average number of vigorous sprouts on stump.	Average height of sprouts.
Inches.					*Feet.*	*Inches.*					*Feet.*
4	11	14	0	14	10.00	23	9	0	42	31	5.58
5	16	11	0	11	6.66	24	26	0	26	12	6.25
6	21	12	2	14	7.25	25	16	0	45	20	5.00
7	18	9	5	12	9.16	26	11	0	38	16	4.50
8	12	7	14	20	9.33	27	14	0	38	18	4.75
9	27	13	20	25	8.75	28	21	1	56	18	4.50
10	31	5	8	13	7.41	29	8	0	46	18	4.66
11	20	8	2	10	8.25	30	36	0	60	20	4.00
12	16	9	30	39	6.66	31	29	0	51	22	4.16
13	32	5	48	53	7.00	32	31	0	44	15	5.08
14	51	7	21	28	7.16	33	20	0	54	21	4.50
15	42	6	17	23	7.66	34	27	0	63	14	3.66
16	23	3	32	35	6.16	35	18	0	37	8	4.25
17	57	2	36	32	7.08	36	25	0	67	10	3.16
18	37	0	42	35	7.16	37	13	0	74	9	3.66
19	7	0	62	20	6.00	38	9	0	35	10	4.58
20	41	1	44	30	5.50	39	5	0	57	12	3.41
21	23	0	24	18	6.16	40	2	0	65	10	3.16
22	10	0	37	22	5.25	41	3	0	61	16	4.58

[1] "The Cottonwood (*Populus deltoides*): A Tree Study," Master's Thesis, by Julius V. Hofmann, University of Minnesota, April, 1912.

The sprouting capacity of stumps also depends upon their age. After 30 years of age it becomes weak and at 45 years almost ceases. Age, however, does not seem to affect the method of sprouting. Apparently the most vigorous sprouting capacity, as determined by the number of sprouts per stump, is somewhere between 15 and 25 years of age. It should be realized, however, that the smaller number of sprouts from stumps below this age is not an indication of lack of vigor, since a small stump can not for physical reasons support as many sprouts as a large one.

The capacity to sprout, like reproduction from seed, is also governed to a great extent by the light supply. Vigorous sprouts do not develop under the shade of the forest. In stands where only the best trees are cut, coppicing, because of the shade of surrounding trees, is almost sure to fail.

Another factor of basic importance in affecting coppice reproduction is the season of cutting. Sprouts readily form after felling in winter or early spring, whereas stumps cut in summer or early fall seldom give rise to thrifty sprout growth.

The conclusions just given apply particularly to the northern part of the Mississippi Valley in the vicinity of Red Wing, Minn. In the lower Mississippi Valley, where cottonwood is of larger commercial importance, very little evidence of this form of reproduction was found. Comparatively few young, vigorous trees are cut. Lumbering usually removes only the larger mature trees, whose sprouting capacity is limited and whose stumps are partially shaded by trees left standing on the ground. Lumbering, furthermore, is usually carried on most extensively in the summer and fall, when the sprouting capacity of the trees is lowest. Probably this combination of circumstances is responsible for the almost entire absence from the lower Mississippi bottom lands of cottonwoods of sprout origin. The adaptability of this system of coppice reproduction to the Mississippi region can be determined, therefore, only after actual experimentation. There is, however, little reason to doubt that young stands of cottonwood in that region can be readily renewed by coppice, provided logging is carried on during the season of most vigorous sprouting and extended also to young trees.

CHARACTER OF STANDS.

Cottonwood occurs both in pure stands and in mixture with other species. Either of these conditions is unstable, the pure stand evolving gradually into a mixed one from which the cottonwood may eventually be eliminated. This is due to cottonwood's demand for full sunlight. As the old trees die they are succeeded by stands of more tolerant species which have come up under partial shade. In fact, the very continuance of cottonwood in natural stands seems

almost dependent upon accidents which result in openings in the stand and thus provide the light needed for the growth of young cottonwoods. The main agencies of this character in the Mississippi Valley are the river itself, which is continually building up new lands, and destructive winds, which often clear wide swaths through the forest.

PURE STANDS.

Cottonwood when young normally grows in pure stands. Since cottonwood reproduction is so dependent on full overhead light, such stands are restricted to sites that at the time of seeding were unshaded. Pure cottonwood is therefore most common on the following situations: (*a*) Newly formed islands and bars built up by deposition; (*b*) old lake and river bottoms which have been filled in by sediment; (*c*) old fields which have been abandoned and have reverted to natural growth; and (*d*) open areas within the forest caused by hurricanes or fires. Probably 90 per cent of the pure cottonwood stands are on exposed areas outside of the river levees. The value of cleared farm land in the Mississippi Valley is so great that practically none has been abandoned in recent years, unless subject to overflow. In many cases mature stands of cottonwood have been cut from such areas in order to use them for farming.

Pure stands are seldom extensive, although in the southern half of the region they are found in more or less solid bodies over hundreds of acres adjoining the river. Pure stands are always even-aged, or at least consist of even-aged groups. Where several age classes are present their arrangement is usually governed by the order of succession in the formation of new land by the river. The youngest stands lie nearest the river on the ground last built up, and as one progresses from the river toward the levees one passes through successive belts of even-aged cottonwood, each very similar to the preceding, except that the age and consequent size become greater and greater. The regularity of this succession, however, is usually broken by stands of black willow.

Pure stands of cottonwood are extremely dense. They undergo very rapid thinning with age, however, as might be expected from fast-growing intolerant trees when starting in dense thickets. It is not unusual to find two-year-old thickets of this character with probably 40,000 living trees to the acre. The seeds, in fact, frequently germinate as close as 2 or 3 inches apart, but thousands of the young plants die from lack of light or moisture very soon after germinating. At the age of 10 years there are seldom more than 700 to 800 trees left, and at 25 years this number is reduced to about 120 trees per acre. (See Pl. III.)

MIXED HARDWOOD STANDS.

Cottonwood grows in mixture either with willow or with other hardwoods. It is more often found with the hardwoods on the better drained glades and ridges throughout the bottom-land areas. The mixture differs in the north and south portions of the valley. The predominating species associating with cottonwood in the upper Mississippi Valley are silver maple, white elm, river birch, sycamore, boxelder, and ash. Other species are butternut, shellbark hickory, black walnut, pin oak, hackberry, and coffeetree. Most of these occur also through much of the lower valley region, especially sycamore, ash, hackberry, and boxelder. Several other species, however, which are abundant in the South, become scarce or entirely disappear from the composition as one proceeds north through the upper valley. This is true particularly of red gum, tupelo, cypress, pecan, willow oak, overcup oak, and cow oak. In addition to those already listed, the following trees of minor value are often found with cottonwood in either or both parts of the valley: Honey locust, black locust, dogwood, mulberry, pawpaw, red elm, redbud, and hawthorn. Perhaps the most characteristic associates of cottonwood in the northern part of the valley are the silver maple and white elm, while sycamore, hackberry, and red gum occur most abundantly with it in the south. Nearly all of the associated species are present in the central sections of the valley, including extensive bottomland areas in Missouri, Arkansas, Illinois, Tennessee, and Kentucky.

In certain parts of the bottoms, three classes of situations supporting forest growth may be recognized, namely, the "glades," the "ridges," and the "back sloughs." The sloughs remain under water during the larger part of the growing season and their characteristic forest growth is cypress and tupelo gum. Cottonwood practically never grows there. The bottoms subject to overflow for from a few weeks to several months are sometimes spoken of collectively as the "glades." These in turn may be irregularly divided by low "ridges," which are seldom over 6 feet in elevation, and often slope almost imperceptibly to the level of the glades. The ridges and the glades, however, are often not clearly defined, and even where they are well marked the forest composition seems to be but little governed by them. Sycamore, pecan, shellbark hickory, and boxelder are possibly more common on the better drained ridges.

In mixed hardwood stands the cottonwood occurs in all proportions from only one to two trees per acre up to nearly a pure stand. Frequently cottonwood occurs in small groups on the lower depressions. Such groups may have 10, 20, or more trees. At times the cottonwood, either single trees or groups, seems to be restricted to higher elevations, apparently because at the time of seeding the

lower land was under water. This indirect influence of topography accounts for much of the variation in the character of occurrence of cottonwood in this mixed stand.

If the cottonwood is well represented in such a mixed stand, there is often almost the appearance of a well-defined two-storied forest, in which the more shade-enduring species, such as elm, sycamore, ash, hackberry, or oak, are partially overtopped by the much faster growing cottonwood. By the fortieth or fiftieth year, however, the stand has usually opened enough to give the associate species room for growth. During the next 50 years these gradually fill in the space left vacant by the death of the cottonwoods. At the age of 100 years such stands may contain less than half a dozen large cottonwoods to the acre.

A pure stand of cottonwoods develops in a similar manner into a mixed stand as the trees reach maturity. In fact, during the early life of the pure cottonwood stands there is often an understory of small sycamore, ash, elm, maple, and other species, which upon examination will generally show the same age as the cottonwoods. These associates, gradually augmented by others that come in as cottonwoods die, ultimately occupy the ground to the exclusion of the latter.

COTTONWOOD-WILLOW STANDS.

In the Mississippi Valley cottonwood is frequently associated with various willows, which compete with it in occupying newly made lands and bars. Black willow (*Salix nigra* Marsh.) is the principal associate in the lower valley, while in the north the almondleaf or peachleaf willow (*Salix amygdaloides* Anderss.) appears to be more common. The latter, together with the small longleaf or sandbar willow (*Salix fluviatilis* Nutt.), which is common throughout the whole region, seems to appropriate nearly all the available open areas along the upper river, affording very little chance for the reproduction of cottonwood, which apparently seeds somewhat later. Cottonwood-willow stands, therefore, are infrequent in the north and usually contain a very small proportion of cottonwood. They are, however, comparatively common in the lower valley. Here the black willow and cottonwood seem to grow on more even terms, and both species make almost equally rapid growth for the first 20 to 25 years. The cottonwood, however, continues to develop, and on many situations may ultimately crowd the willow out of the stand. Since, however, the latter seems to be better adapted to poorly drained land, it is not uncommon to find it crowding out the cottonwood on wet, mucky soils. The cottonwood-willow stands are therefore of a very temporary character, few being over 30 years

old. For this reason they are of comparatively little importance from the standpoint of management.

FORM AND GROWTH OF INDIVIDUAL TREES.

Cottonwood is one of the tallest trees east of the Rocky Mountains. Under favorable conditions it attains a height of more than 175 feet, and mature trees within its optimum range are seldom less than 125 feet high. The maximum height recorded by the Forest Service is 190 feet. Diameters of from 4 to 6 feet are not unusual (Pl. I), and trees on well-drained bottomlands in the Mississippi Valley have measured nearly 10 feet through at the stump.

In forest stands of average density, cottonwood prunes itself of branches remarkably well, producing a long, straight bole, clear of limbs for a distance of from 60 to 80 feet, with comparatively little taper. The crown remains narrow and pointed until the trees reach 25 to 40 years of age, after which it becomes more branchy and spreading. In the open or when planted in single rows, cottonwood produces a short, stocky stem, which is likely to divide within 20 or 30 feet of the ground into several large, irregular branches, forming a long, open, wide-spreading crown.

Cottonwood develops a stout taproot from 3 to 6 feet long, reenforced by numerous wide-spreading laterals. Wherever successive layers of alluvial soil are deposited by the river about the base of the tree, new side roots appear to develop along the buried part of the trunk.

The bark of mature trees is extremely thick and rough, and firmly attached. At 10 years the bark at the base of the tree averages about half an inch in thickness; at 35 years, about an inch; and on old trees sometimes more than 2 or 3 inches. The bark is characterized by rough, narrow ridges, separated by wide, irregular connecting furrows. (Pl. I.)

Notwithstanding its large dimensions, cottonwood seldom reaches great age. It is unusual to find sound trees of this species over 125 years old. The maximum age recorded by the Forest Service is 166 years, and it is probable that 200 years is about the maximum longevity of the species.

It is a tree of remarkably fast growth, especially during early life. After about 40 years of age, however, the growth rate in height declines rapidly, although the trees continue to increase in girth at a moderate rate. On alluvial bottomland soils which are fairly well drained an average annual height growth of from 4 to 5 feet and a diameter growth of two-thirds of an inch are not at all unusual for the first 25 years. Trees have been measured that were 83 feet tall at 12 years and 100 feet at 15 years. Table 3 shows the average

height and diameter of bottomland trees at different ages. Even on fresh, well-drained upland situations, where cottonwood seldom occurs naturally, planted trees will easily increase 2 to 3 feet in height annually for the first 20 years.

GROWTH AND YIELD OF STANDS.

The most important question in considering the growth of a species is, How much wood will it yield per acre? The growth of cottonwood stands was determined by means of 100 sample plots laid off in pure stands of cottonwood on overflow lands in the lower Mississippi Valley.

The growth of stands depends on the growth of the individual trees and on the number of trees per acre. Pure stands of cottonwood are open in character. Table 3 shows the average number of trees per acre at different ages. It is apparent from this table that the rapid growth of individual cottonwoods is to some extent offset by the comparatively small number of trees to the acre. At 35 years 59 trees remain, of which 53 are 14 inches and over in diameter. By 40 years the total has diminished to 48, nearly all of which are at least 14 inches in diameter. The rapid decrease in number is apparent when it is seen that at 10 years there were 699 trees, at 20 years 163, and at 30 years only 80. (See Pl. IV.)

Because of the open character of cottonwood stands very heavy yields of lumber per acre are rare. By utilizing all trees down to 14 inches on the stump to a top diameter of 12 inches, it is doubtful if even the best pure stands will cut over 40,000 board feet per acre. Yet, considering the early age at which cottonwood reaches merchantable size, the yield compares favorably with that of such trees as white pine and Douglas fir, which, though larger, take a much longer time to reach such size. Measurements of a large number of plots in the Mississippi River region show that fully stocked pure stands yield an average of 31,000 feet board measure in 40 years, and that some stands at this age will cut as high as 36,000 feet to the acre.

Table 3 gives the average yields from fully stocked stands of cottonwood at different ages in board feet and cubic feet. The average annual yield of a stand is obtained by dividing the total yield per acre by the age. From Table 3 it is apparent that the number of board feet produced per year is greatest when the stand is about 35 years old, after which the average annual production gradually falls off. Theoretically, therefore, the best time to cut cottonwood is when its average annual production begins to decline. As shown later, however, other factors may affect the time of cutting.

TABLE 3.—*Growth and yield of cottonwood (Populus deltoides Marsh) in pure, fully stocked stands in the Mississippi Valley.*

Age.	Number of trees per acre.		Average size.		Yield per acre.			Average annual yield per acre.		
	14 inches and over.	All trees.	Diameter breast-high.	Height.	Stem wood.	Scribner decimal.	Doyle.	Stem wood.	Scribner decimal.	Doyle.
Years.			*Inches.*	*Feet.*	*Cu.ft.*	*Bd.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Bd.ft.*
5	..	.....	2.0	22	650	.....	.....	130	...	...
6	..	.....	2.8	29	875	.....	.....	146	...	...
7	..	1,450	3.5	36	1,025	.....	.....	146	...	...
8	..	1,163	4.2	43	1,250	.....	.....	156	...	...
9	..	900	5.0	49	1,500	.....	.....	167	...	...
10	..	699	5.7	56	1,800	.....	.....	180	...	...
11	..	558	6.4	61	2,175	.....	.....	198	...	...
12	3	452	7.1	67	2,600	.....	200	217	...	17
13	8	375	7.8	72	3,050	800	700	235	62	54
14	15	320	8.5	76	3,500	1,600	1,300	250	114	93
15	22	276	9.2	81	3,850	2,400	1,900	257	160	127
16	29	243	9.8	85	4,150	3,200	2,600	259	200	163
17	34	217	10.5	88	4,400	4,000	3,300	259	235	194
18	37	195	11.1	92	4,575	4,900	4,100	254	272	228
19	40	178	11.7	95	4,750	5,800	4,900	250	305	258
20	43	163	12.3	97	4,900	6,600	5,700	245	330	285
21	45	150	12.8	100	5,025	7,600	6,500	239	362	310
22	47	140	13.4	102	5,125	8,600	7,500	233	391	341
23	49	130	13.9	104	5,250	9,600	8,400	228	417	365
24	50	121	14.5	106	5,350	10,700	9,500	223	446	396
25	52	114	15.0	108	5,450	11,900	10,700	218	476	428
26	53	106	15.5	109	5,525	13,200	12,000	213	508	462
27	54	99	16.0	111	5,600	14,700	13,400	207	544	496
28	55	92	16.5	112	5,675	16,300	15,100	203	582	540
29	55	86	16.9	114	5,750	18,100	17,100	198	624	590
30	55	80	17.4	115	5,825	20,300	19,200	194	677	640
31	55	75	17.9	116	5,875	22,700	21,400	190	732	690
32	55	70	18.3	117	5,950	24,900	23,500	186	778	734
33	55	66	18.8	119	6,025	26,800	25,300	183	812	767
34	54	62	19.3	120	6,075	28,300	26,600	179	832	782
35	53	59	19.7	121	6,150	29,400	27,500	176	840	786
36	52	57	20.2	123	6,200	30,100	28,200	172	836	783
37	51	53	20.6	124	6,275	30,400	28,700	170	822	776
38	50	51	21.1	125	6,325	30,700	29,100	166	808	766
39	49	50	21.5	126	6,375	30,900	29,300	163	792	751
40	48	49	22.0	127	6,425	31,000	29,300	161	775	733
41	46	48	22.4	128	6,475	31,000	29,400	158	756	717
42	45	45	22.9	129	6,525	31,100	29,500	155	740	702
43	44	44	23.4	130	6,575	31,000	29,500	153	721	686
44	43	43	23.8	131	6,625	31,000	29,500	151	705	670
45	42	42	24.2	132	6,675	30,900	29,500	148	687	656
46	40	40	24.7	133	6,725	30,800	29,500	146	670	641
47	38	38	25.1	134	6,775	30,700	29,500	144	653	628
48	37	37	25.6	135	6,825	30,600	29,500	142	638	615
49	34	34	26.0	136	6,875	30,500	29,500	140	622	602
50	32	32	26.5	136	6,900	30,300	29,400	138	606	588

Similarly, the current annual production in cubic feet or cords per acre culminates at the age of 12 years, at which time approximately 500 cubic feet per acre annually is being produced. The average annual growth, however, continues to increase up to 16 years, when it attains 255 cubic feet per year, against only 221 cubic feet at 12 years. It is plain, therefore, that if the object of growing cottonwood is to produce the maximum amount of solid wood per acre per year, a rotation of approximately 16 years will give the desired results. The reason why the average annual growth in board feet per acre culminates later than the average annual production in cubic feet is because the board-foot production does not begin until the

trees are about 12 years old and because the number of board feet to each cubic foot increases as the tree increases in size. In logs of large diameters each cubic foot will saw out more than 7 or 8 board feet, whereas in small logs there may be only 2 or 3 board feet.

Table 4 gives the yield of pulpwood for stands from 5 to 20 years old under the most favorable conditions of growth. Older stands are not considered, because the maximum average annual yield in cords per acre occurs at a considerably earlier age than 20 years.

TABLE 4.—*Yield of pulpwood per acre in the lower Mississippi Valley.*

Age.	Total yield.		Average annual yield.	Age.	Total yield.		Average annual yield.
Years.	*Cubic feet.*	*Cords.*	*Cords.*	*Years.*	*Cubic feet.*	*Cords.*	*Cords.*
5	630	6.6	1.3	13	4,460	47.0	3.6
6	810	8.3	1.4	14	4,690	49.4	3.5
7	1,020	10.7	1.5	15	4,830	50.8	3.4
8	1,320	13.9	1.7	16	4,910	51.7	3.2
9	1,700	18.0	2.0	17	4,960	52.2	3.1
10	2,330	24.5	2.5	18	4,990	52.5	2.9
11	3,100	32.6	3.0	19	5,010	52.7	2.8
12	4,050	42.6	3.5	20	5,020	52.8	2.4

The volumes of the trees were determined up to a top diameter of 4 inches inside the bark, except where the stem was too crooked or branchy. The cubic-foot volume was converted into cords by dividing it by 95, a liberal factor for converting solid cubic feet into stacked measure. The cordwood figures are for peeled wood. Where unpeeled wood is purchased with the intention of running it through a barking machine at the mill these figures will be too low. The bark constitutes about 22 per cent of the total volume. The figures in the table therefore represent only 78 per cent of the total cubic contents. The largest average annual yield is obtained at 13 years, at which time there is a total stand of 47 cords. The growth and yield tables are naturally restricted in their application to cottonwood stands in the central and southern United States, where the measurements were made, and particularly to overflow lands along the rivers and streams. Observations on the growth of cottonwood in Iowa and Minnesota would seem to indicate, as might naturally be expected, that the yield in the northern part of the country would fall considerably below that in the South.

It was difficult to find pure cottonwood stands in Iowa and Minnesota in which normally stocked plots could be laid off. Only a half dozen plots were measured, ranging from 25 to 55 years. The results are given in Table 5.

TABLE 5.—*Yield of cottonwood stands on upland soil in Iowa and Minnesota.*

Location.	Age.	Number of trees per acre.	Average diameter breast-high.	Average height.	Yield per acre, Scribner.		Remarks.
					To 12-inch top.	To 10-inch top.	
	Years.		*Inches.*	*Feet.*	*Bd. ft.*	*Bd. ft.*	
Lee County, Iowa	25	108	13.0	80	1,700	5,100	Scattered, with many associate species.
Do	25	88	13.8	82	4,100	6,600	Do.
Allamakee County, Iowa.	45	131	15.3	84	12,900	15,600	Pure stand.
Jackson County, Iowa.	50	80	18.3	100	15,800	18,100	Very dense pure stand.
Monona County, Iowa.	55	88	16.5	94	13,100	16,800	In Missouri Valley, less humid climate, dense, pure.
Scott County, Minn.	56	25	24.8	107	15,000	18,100	Maple, elm, ash, etc., in mixture.

It is probable that some of these stands have been cut to a slight extent, but it is not likely that on upland soil in this region cottonwood will cut more than 20,000 feet per acre at 50 years of age. At this age, however, it has already reached maturity and is losing rather than gaining. Yields of between 15,000 and 20,000 board feet ought to be possible in 35 to 40 years. One or two plantations in Iowa on good bottomland soil have yielded more, as may be seen from Table 6.

TABLE 6.—*Yield of cottonwood on bottomland soil in Iowa.*

Location.	Age.	Number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre.	Original spacing.
	Years.		*Inches.*	*Feet.*	*Bd. ft.*	*Feet.*
Harrison County	34	126	14.5	87	23,850	7½ by 6
Monroe County	35	137	13.3	77	24,500	8½ by 8½

At least one of the plantations has occasionally been thinned. Moreover, the trees had plenty of room for early growth, and it is probable that they were cultivated for the first few years. In the case of these plantations, however, the estimates take in all straight logs to a top diameter of 6 inches, for even such small-sized material is actually sawed up for farm use. Considering, however, only logs 10 inches and over in diameter, northern stands of cottonwood will probably seldom yield more than two-thirds as much saw timber as stands of the same age in the lower half of the valley.

MANAGEMENT.

ADAPTABILITY OF COTTONWOOD.

If cottonwood stands are to be maintained permanently some system of management is essential. Its demand for plenty of direct

light must in particular be fully met. In logging mixed stands the trees which are of little value to the lumbermen, and are therefore commonly left standing after the removal of the cottonwood and many other merchantable species such as ash, red gum, or oak, should also be taken out. The shade cast by these weed trees and by underbrush tends to prevent the reseeding of the area to the light-demanding cottonwood. Rarely does one find good restocking of this species except on wide clean openings, such as are sometimes made by hurricanes or by laying out logging roads, drainage ditches, and the like.

Even in pure cottonwood stands it is unusual to find satisfactory restocking after logging, under present methods. Pure stands after 40 or 50 years' growth thin out and expose the forest floor to sunlight, thereby inducing the entrance of undergrowth, such as poison ivy, pepper vine ("cow itch"), briers, dogwood, and privet, and occasional seedlings of the more tolerant species. After logging operations such growth is left in control of the area, and usually prevents the reproduction of cottonwood. Moreover, pure stands on the more recently made land along the river are sometimes culled over for the largest timber before all the trees are merchantable. This serves further to open up the stand. It is customary to cull pure stands on islands and bars along the river several times, at intervals of 5 to 10 years. Under such conditions there is little chance of securing cottonwood reproduction after the final cut, unless all undergrowth is removed and cottonwood is planted.

The opportunity for managing cottonwood conservatively in the Mississippi bottoms is in some respects unparalleled. Nowhere else in the United States are there large areas of overflow bottomland unfit for agriculture which can be bought for from $3 to $5 an acre. Taxes on the land form scarcely any burden. In parts of the valley all unimproved land outside the levees is assessed at a uniform value of $1 per acre. In the South the assessed value rarely exceeds $2 or $3, with a tax rate of about 20 mills. Fire hazard is usually negligible, due to the annual spring floods, which carry away a large proportion of the inflammable material. It is true that much of this material is again deposited along the river banks, but, as a rule, on such situations growing cottonwood on a commercial scale is out of the question. Whatever débris remains in the cottonwood stands after a flood, being water soaked, decays rapidly. Furthermore, even when fire is a menace, cottonwood at the age of 15 or 20 years has formed comparatively fire-resistant bark from one-third to two-thirds of an inch thick.

Neither insects nor fungi seem to be a serious menace to cottonwood in the Mississippi Valley. This comparative freedom from disease is probably due largely to the favorable conditions for forest growth characteristic of rich, alluvial lands. Trees which are making vigor-

ous growth on soils naturally adapted to their requirements are not predisposed to disease. Such trees if accidentally injured by wind, fire, or other agency, more readily heal over the wound. Cottonwood, in particular, grows so rapidly that even large wounds do not long remain exposed to infection by fungi.

Another important condition favoring management of the bottomlands is the ease of getting the timber out. The land best suited to the practice of forestry lies for the most part within 2 or 3 miles of the river, which is generally used for transportation. This renders logging inexpensive and obviates the necessity of constructing railroads. It also makes it feasible to leave seed trees which can be easily taken out after they have restocked the ground and at a cost per thousand feet but slightly in excess of that for the first operation.

Furthermore, cottonwood is commercially very valuable and is one of the fastest-growing trees in the United States. It yields lumber of good quality within 30 to 35 years. Seed production, moreover, is abundant and frequent. Under such favorable circumstances owners of cottonwood stumpage should give more attention to securing new crops of timber after lumbering on lands unfit for farming.

AREAS AVAILABLE FOR GROWING COTTONWOOD.

Though large areas of the Mississippi bottomlands, especially in southeastern Missouri and northeastern Arkansas, are being made tillable through extensive drainage projects, and still other areas will be reclaimed for farming by the extension of the present levee system, there are extensive tracts of rich alluvial land subject to annual overflow of from one or two weeks to several months which afford ideal conditions for the growth of cottonwood. Probably the largest part of this unprotected land is in the lower valley, yet from Cairo, Ill., to the head of the river there are in the aggregate large areas better adapted to forest growth than to agriculture. The total area of such unprotected land south of Cairo, Ill., is approximately 1,500,000 acres, distributed as follows: From Cairo to the mouth of the White River, 690,000 acres; from the mouth of the White River to Warrenton, Miss., 500,400 acres; and from Warrenton to the Head of the Passes, 277,000 acres. While a portion of this unprotected land is sufficiently elevated to warrant cultivation, not more than 10 or 15 per cent is at present in crops. Back of the levees there is considerable land poorly adapted to agriculture, such as sandy ridges or the beds of old sloughs which may still be inundated in very wet periods. While farm crops may be grown on the ridges for a few years, the soil soon becomes unproductive. In addition, there are bottomlands bordering many tributaries of the Mississippi, such as the Red, Arkansas, Yazoo, and St. Francis Rivers, which because of poor drainage or annual inundation are unsuited for farming.

Tree growing on lands outside the levees is to some extent hazardous on account of the erratic movements of the river. Through the tremendous erosive power of the Mississippi its banks are continually caving in and its course changing. Of the 1,500,000 acres of unprotected land now available for timber production there may be, at the end of 35 years, the period required to produce a merchantable stand of cottonwood, nearly a million acres unaffected by the river's action. Attempts at systematic management of cottonwood in this region should therefore be confined to areas where the river will not encroach upon the timber before it has matured. A fairly close approximation can usually be made of the distance which the river will cut back into the present bank within a given period of years by comparing the distance cut during the same number of years in the past.

PURE STANDS.

Cottonwood will not tolerate shade. Direct overhead light is essential at all stages of its growth. Cottonwood should therefore be logged clear. The common practice of cutting to a diameter limit, which removes only the largest trees, is entirely unsuitable. Cutting the largest trees enables the stumpage owner to make the first cut earlier, i. e., while many of the trees are still unmerchantable, and to cut the remainder within from 5 to 6 years, when they have had the benefit of the increased light. Sometimes an area is cut over three times in 10 years. After each cutting vines and low shrubs spring up in abundance and almost entirely preclude natural reproduction. These conditions justify the removal in one cut of all the cottonwood on the ground that can be profitably handled, regardless of its possibilities of growth if left for another 5 or 10 years. Twenty or 30 small trees, 15 to 18 inches in diameter breasthigh, yielding perhaps 3,500 or 4,000 board feet, might in another 10 years cut 10,000 board feet. These 10 years, however, represent nearly a third of the time required to grow a stand which will yield 29,000 feet per acre. If it is remembered also that by gradual cutting the initial cost necessary to clear away the excessive undergrowth is much increased the greater profitableness of the clear cutting system is evident.

NATURAL REPRODUCTION VERSUS PLANTING.

Under the clear cutting system the renewal of the stand may be obtained either by natural reproduction, secured by leaving seed trees on the cut-over area, or by planting. Natural and artificial restocking both have definite advantages. Other things being equal, planting is likely to be more costly, since it entails the raising or purchase of planting stock and the labor of setting it out. The cost of natural reproduction is represented by the value of the

seed trees if they are never utilized, or by the extra cost of removing them if they are taken out later. Planting, then, requires a cash outlay. Natural reproduction requires merely a curtailing of present profits. The greater present returns when no seed trees are left may often go a long way toward defraying the expense of planting.

It is questionable if planting would be wise where there is a reasonable certainty of securing new stands from natural seeding. Wherever conditions are favorable to seed germination, as on lands subject to overflow in the spring, but which is only moist when the seed falls, and is free from shrubs, vines, or herbaceous plants, natural reproduction is reasonably certain and less costly than planting. On low ridges or where spring overflow is uncertain, complete dependence can not be placed upon natural reproduction.

Planting insures a uniformly stocked stand; the spacing of the trees can be so regulated as to obtain more rapid growth during early life, thus shortening the rotation, and there is less chance of complete failure due to weeds or undergrowth, the absence of high water, or an unusually late flood which washes away the seed. On land where reproduction by either method is difficult planting is preferable. Planting, therefore, will in the future probably be preferred to natural reproduction in the Mississippi Valley.

REPRODUCTION BY SPROUTS.

Natural reproduction may be obtained either from sprouts or from seed. For several reasons sprout or coppice reproduction will probably be of comparatively minor importance in the lower valley. First, few stands of cottonwood less than 35 years old will be cut, by which time the sprouting vigor of the stumps has weakened. It is questionable whether sprouts from stumps of this age, even though originating at the root collar, will produce as large and vigorous trees as the parent stock. The sprouting vigor declines steadily after the tree is 20 to 30 years old. At this age the number of trees per acre is small. Consequently the sprouts would not form a sufficiently dense stand to clear themselves readily of side branches. These difficulties may be overcome, as, for example, by supplementing coppice growth by planting or natural seeding. From present indications it would seem that sprout reproduction is applicable only to stands managed for pulpwood on a rotation of 10 or 12 years. Pulpwood companies in the North which are planting this species will undoubtedly find the sprouting of cottonwood of great value in securing second growth. The coppice system of reproduction entails but small initial expense, and because of rapid growth makes possible short rotations. The young age of trees taken for pulpwood and the low stumps which it is possible to cut will insure vigorous sprouting from the root collar. Six inches should be the maximum

stump height. The trees should be cut during the winter or early spring and the ground be completely cleared in order to allow the coppice full sunlight. The only actual outlay necessary in securing a stand by this method will be that in connection with cutting back in July and August all but the most vigorous, well-formed sprouts on each stump. A system of this kind carried on in certain South American plantations of Carolina poplar (see p. 1), a male form of the cottonwood, is said to result in actually shortening the rotation from 10 to 7 years, or 30 per cent.

Where timber production is the object of management, reseeding or replanting the area will be the common method.

SEED TREES.

In a clear-cutting system abundant seed production and uniform seed distribution are of first importance. The next essential is a ground in condition suitable for germination of the seed and growth of the seedlings. Cut-over areas may often be seeded by adjoining timber. This is likely to be the case where the cutting areas are comparatively small, and where there are enough cottonwoods to restock the ground. Since pure stands of cottonwood are seldom more than a few hundred acres in extent and are usually long and narrow, paralleling the course of the river, reproduction from the adjoining stands should be successful wherever there are plenty of seed trees on the windward side of the tract to be seeded.

For natural restocking the seed of cottonwood can not be depended upon to scatter farther than 600 feet from the mother tree. Unless the cut-over area is less than 600 feet in width seed trees should be left on the area itself.

Seed trees represent an investment equivalent to the extra cost of logging them later after they have restocked the ground. If of poor quality for lumber, however, and very expensive to handle in a return cutting, they may be sacrificed, in which case the investment is represented by the actual stumpage value of the timber they would cut.

Seed trees should be left uniformly scattered over the area. They should be located with reference to the direction of the winds at the time of seeding. To facilitate the subsequent removal of the seed trees they may be located roughly in rows at right angles to the direction of the wind. This arrangement will permit the removal of the timber with the minimum amount of damage to the young growth, since all the logs from a given row may be hauled over the same logging road.

One mature seed-bearing tree reserved on each acre of cut-over land should be ample to restock the ground, and would allow for

windfall and breakage. If in the end two seed trees remained to even 3 acres, reproduction should be excellent. Since seed is borne in abundance each year, the trees will rarely be needed for longer than a year or two. One seed tree per acre would be equivalent to leaving parallel rows about 600 feet apart, with the trees approximately 50 feet apart in the rows.

In reserving seed trees the following considerations should be taken into account:

(*a*) Only female trees should be selected for seed production. Unfortunately, there seem to be no characteristics other than the flowers by which male and female trees may be readily distinguished. Seed trees should therefore be marked during the flowering or seed-bearing season. The flowers of the seed-producing trees are not conspicuous. They occur in the form of slender catkins, 6 to 10 inches long, on which the budlike flowers appear very small and scattered. During the seeding time the abundance of light "cotton" shed by these female catkins readily distinguishes the seed-bearing trees. The flowers of the male trees are, on the other hand, more showy—bright red or yellow in color—and the catkin fuller, wider, and denser, but not as long as the female catkin.

(*b*) In addition to one seed tree per acre, a number of male trees should also be left in order to insure proper fertilization of the female flowers. Fertilization is believed to be effected usually by insects, which carry the pollen from the staminate to the pistillate flowers. About every fourth tree should be a staminate one.

(*c*) Seed trees as far as possible should be the least merchantable individuals, since in this way the investment represented by the stumpage value of the trees left after logging is the least, whether they are later removed or not. Seed trees, however, should be thrifty and vigorous. Crooked, forked, or branchy trees, which would cut out a comparatively small amount of high-grade lumber, are usually just as vigorous and as suitable for seed production as the tall, clear, straight individuals. In fact, the larger the crown, the more seed is produced.

(*d*) Only windfirm trees should be left. On low, wet sites, where the soil is loose and soft, no seed trees should be reserved.

(*e*) Seed trees should be removed as soon as possible after young growth has become established, otherwise the shade will check the growth of many of the younger trees. There is less injury to the young growth if the seed trees are cut and removed before it attains much size. Since cottonwood often grows at the start at the rate of from 5 to 7 feet a year, it is advisable to cut the seed trees the year the young growth is established. If for any reason they can not be profitably removed and are likely to deteriorate before the next lumbering operation, it may sometimes be advisable to deaden them

FIG. 1.—MERCHANTABLE STAND OF PURE COTTONWOOD, 44 YEARS OLD, SHOWING CHARACTERISTIC STRAIGHT, CLEAR GROWTH.

FIG. 2.—PURE COTTONWOOD THICKET, 10 YEARS OLD, SHOWING EARLY DENSITY.

OVERMATURE SCATTERED COTTONWOODS WITH SMALLER UNMERCHANTABLE ASSOCIATES.

so that their shade may not suppress any of the young growth. Most pure stands, however, are accessible to the river, which makes it practicable, as a rule, to return for any seed trees within a year or two of the first cut. With only a few logs to handle it will often be possible to wait till high water and then float them out to the river bank, thus obviating the much greater expense of hauling. In such cases there would probably be no extra expense connected with leaving seed trees. If hauling were necessary, however, it might cost fully 50 per cent more to get out this scattered material. After the short interval of only a year or two, little if any additional swamping would be necessary to open up the former logging roads, but the haulers would lose considerable time in locating and loading the scattered logs and would probably get out no more than two-thirds as much per day as when working in heavier stands. If hauling under ordinary conditions costs $3 to $4 per thousand, it might increase in the latter instance to from $4.50 to $6 per thousand. The additional $1.50 to $2 per thousand feet would then represent the cost of leaving seed trees. If these are left as recommended, they should not average over 750 board feet per acre, which would make their cost at most run from $1.20 to $1.50 per acre.

PREPARATION OF THE GROUND.

Pure thickets of cottonwood, up to 20 or 25 years at least, are quite free from undergrowth, but at the age of 30 or 35 years a large variety of shrubs, vines, and weeds usually come up under the main stand. Such growth consists largely of peppervine, poison ivy, briers, privet, dogwood, and innumerable species of herbaceous character. In the more open mature stands undergrowth and weeds often cover most of the ground. In addition, there are often numerous suppressed or overtopped trees of less valuable species, such as sycamore, hackberry, and elm. Such trees are usually small, but if left after lumbering would soon develop spreading crowns and shade much of the area. All such growth is detrimental to cottonwood reproduction. To insure natural renewal of the stands, therefore, it will not be sufficient merely to leave seed trees, but in addition the ground must be cleared of all undergrowth. If the resulting slash is very abundant, it may be best to pile it with the cottonwood tops. In normally dense stands, however, this will seldom be necessary, since here the brush is not rank. Burning the slash will seldom be of benefit, except in the case of a rank growth of cane or weeds, which may be killed off by a carefully controlled surface fire. Surface fires do not run rapidly in most parts of the bottoms because of the small amount of inflammable material. Dry cottonwood leaves, moreover, are said to be much less inflammable than those

of most other hardwoods. In burning cane, briers, grass, and weeds special care is nevertheless advisable to keep the fire under control, and where adjoining stands of young timber might be injured it may even be important to surround the burning area with plowed furrows for fire lines.

No preparation of the ground is adequate which fails to leave the mineral soil exposed. Burning of slash under some circumstances may be sufficient, but as a rule it will be necessary to drag the surface with a spike-toothed harrow or similar implement. The cost of dragging should seldom exceed 50 cents per acre. Swamping of small trees and undergrowth can usually be effectually done for $1.50 to $2 per acre, making a total of $2 to $2.50 per acre for the preparation of the ground. In many bottom lands, however, half of this amount will be enough.

Grazing of hogs in the bottoms may serve to expose the mineral soil even better than dragging. Cattle, sheep, and goats may likewise assist in reducing the herbaceous growth. If logging is carried on during the summer, the underbrush and weeds will often get quite a start before the seed ripens the following spring, unless grazing is encouraged. As soon as reproduction starts, however, grazing should cease.

From the standpoint of preparing the ground there is plainly an advantage in logging during the late summer and fall, say from August to November, inclusive. Very little growth of weeds, grass, cane, etc., will come up on cleared areas after the first of August, and, moreover, the sprouting capacity of bushes and trees is low during these late months. Conditions in the bottoms will seldom permit of logging in the spring early enough to prepare the ground for the cottonwood seed of the same season. Wherever feasible, winter operations are entirely consistent with good management.

Proper preparation of the ground, however, will, in many instances, be out of the question. Where the undergrowth is especially dense and consists of vines, such as poison ivy or peppervine, the cost of eradicating it will frequently be prohibitive. Such areas can only be planted.

MIXED HARDWOOD STANDS.

Where cottonwood is the only species of great commercial importance on an area the aim should be to favor it alone. If, however, valuable species are growing with it, some of these may be favored as well. By favoring other species along with cottonwood the liability of total failure in securing reproduction is reduced. Another advantage is the beneficial effect of the other trees upon the cottonwood itself in shading the forest floor, thus preventing the

growth of vines and underbrush. They will also help to clear the cottonwood of side branches.

The most valuable associates of cottonwood are green and white ash, the various red and white oaks, and red gum. Only ash and oak command higher stumpage values. Red gum is now much less valuable on the stump, and, like the other associates, is much slower growing. Assuming a stumpage value of $5 per thousand for cottonwood, the following figures would be typical for its associates, if of good quality: red gum, $2; oak, $5 to $7; ash, $6 to $10; cypress, $5; elm, $2. The less important species, such as hackberry, sycamore, boxelder, river birch, and silver maple, usually have little, if any, value for lumber, although under certain conditions they may sometimes be worth from 50 cents to $1 for fuel, especially in the north of the valley.

The high value of ash makes it one of the most desirable species to encourage in the bottoms. Measurements in the northeastern section of Arkansas indicate that in comparison with cottonwood the greater value of ash timber is to a large extent offset by its much slower growth. Ash, however, is used in much smaller sizes than cottonwood, as in the manufacture of tool and implement handles and oars.

Red gum is more abundant and more extensively used for lumber in the South than is cottonwood. Its use is increasing, and it reproduces readily. Thus, although its present stumpage value is low and its growth much less rapid than that of cottonwood, it will often be advisable to encourage red gum in restocking logged-over areas.

The faster growing oaks, especially red and willow oak, are also of sufficient importance to encourage to a certain extent, particularly on the higher portions of the bottoms. They do not grow as fast as cottonwood, but produce more valuable wood.

SEED TREES.

As in pure cottonwood, a clear cutting system with provision for seed trees is the only means of securing reproduction of cottonwood in mixed stands. It is likewise adapted to the other valuable species, except oak. Red gum's intolerance of shade is probably exceeded among the bottomland species only by cottonwood itself. Ash when young will endure partial shade, but during most of its life full light is essential to rapid growth. The prolific regeneration of these three species on old fields and other openings where the mineral soil is exposed confirms the advisability of clear cutting.

The selection of seed trees in mixed stands should be governed by the same general considerations as in pure stands. Since all gum and oak trees bear seed, selection of seed trees is easy. Seed

of ash and gum are heavier than that of cottonwood, and therefore more seed trees are required per acre to insure dense restocking. Acorns can not be scattered for any distance by the wind, and therefore natural reproduction of oak can not readily be secured under a clear cutting system with seed trees. The best way to encourage oak in a cottonwood stand is to preserve young, thrifty immature trees wherever they occur. In swamping, or in cutting or deadening inferior species, the aim should be to save the oaks and free them from crowding. Besides forming part of the next cut, they will reproduce to some extent.

One cottonwood seed tree per acre will usually be adequate for seed purposes. Where either ash or gum are present the total number of seed trees per acre of all species should be from three to four. On cut-over areas completely in possession of weed trees it is useless to leave cottonwood to reproduce beneath thin shade. Here ash will sometimes meet the demand, since it will reproduce under moderate shade, but in its absence little can be done to keep boxelder, sycamore, hackberry, and other species of doubtful value from taking complete possession of the ground.

PREPARATION OF THE GROUND.

Preparation of the ground in mixed stands should be about the same as in pure stands. The shade in mixed stands is ordinarily more dense than that in stands of pure cottonwood. Consequently, there is likely to be less underbrush and vines, and slashing of undergrowth is correspondingly less troublesome.

In mixed stands, however, the problem is usually somewhat complicated by the presence of many inferior trees which have no merchantable value. Proper ground preparation in these stands will entail an outlay for removing or deadening these undesirable associates. Where conditions are favorable to cottonwood reproduction, it would hardly seem justifiable to leave scattered inferior species merely in the hope that within a few years they may acquire commercial importance. An expenditure of $2 or $3 at most per acre in deadening these trees should result in the establishment of a valuable young cottonwood stand, which otherwise might be indefinitely delayed.

Where, however, the unmerchantable species are very numerous the cost of deadening will often be prohibitive and the reproduction of cottonwood impracticable.

Deadening is often a questionable course, in that numerous dead trees scattered over an area afford breeding places for insects which might later prove injurious to sound trees. Moreover, there is no positive assurrance that satisfactory reproduction will follow. It

is, however, a very common method of clearing bottom lands in the Mississippi Valley for agricultural purposes. On areas subject to overflow cottonwood reproduction is almost certain to follow if seed trees are present. All said, however, deadening is probably preferable to leaving the inferior species where the owner is prepared to make an actual investment for the sake of insuring future cottonwood stands. Only the largest trees, such as could not readily be felled with several strokes of the ax, should be girdled. The cost of deadening, as well as swamping, piling, and burning of the smaller growth, can usually be kept within $2.50 per acre. On many areas from $1 to $2 would put the ground in good condition for cottonwood seeding. Where the cost exceeds $3 deadening will probably, as a rule, be considered inexpedient.

In this connection the question of brush disposal should also be considered. There seems to be no possibility at present of utilizing cottonwood tops in any practical manner. They make very little brush and decay quickly, even though left unlopped. Moreover, they may be carried away by high water. There will be little to gain, therefore, in burning the brush, either for the sake of fire protection or the encouragement of reproduction. However, where much undergrowth and small, inferior trees must be swamped out, it may often be advisable to pile such material with the tops and burn it when partly dry. In thick cane or grass, tops and other brush will burn, even if left scattered. If the ground is to be dragged to expose the mineral soil, piling would be advantageous.

COTTONWOOD-WILLOW STANDS.

Cottonwood and willow are usually associated only in comparatively young stands. Either cottonwood is crowded out by the willow during the first 20 years or it overtops and kills out the willow. If any willow is left at the time of logging, it should certainly be removed, since it is distinctly inferior for lumber. If it can not be disposed of for pulp wood, charcoal, or woodenware, for which uses it is well suited and frequently in considerable demand, it should be cut or girdled. If cottonwood is cut for pulp in young mixed stands, the willow should also be taken, and any adjacent stands of pure willow removed at the same time. Young willow is generally in demand for revetting the river banks and should be disposed of without difficulty.

CLOSER UTILIZATION.

Close utilization is the first step in the proper handling of cottonwood stands. Every tree that will make a merchantable log should be cut, stumps should be low, and the trees utilized as high as possible into the tops. High stumps are often left because the trees are cut at

a time when the water is up. Stumps are sometimes from 8 to 16 feet high. Wherever practicable no stumps should be left higher than 30 inches unless the butts are defective.

More material is wasted in tops. Small logs should not be left in the woods if they can be handled profitably. Such logs saw out little above the grade of No. 2 common, which usually sells f. o. b. at the mill for from $12 to $15 per thousand. On expensive logging operations the actual cost of delivering these logs at the mill and sawing them may so nearly approximate this price as to allow no profit. Most of the mills sawing cottonwood are now taking logs as small as 14 inches and under favorable logging conditions many concerns can utilize straight top logs comparatively free of knots as small as 12 inches at the top. Most of the mills sawing cottonwood which have a daily capacity of over 50,000 board feet are located in the larger towns along the river or at the edge of bottom lands, necessitating a long haul. Small portable mills located on the tract can often utilize with profit logs as small as 10 inches in diameter at the top. Although only one mill of this type was observed in the lower Mississippi Valley, it is probable that in the future the small mill may make possible a closer utilization of cottonwood. In the northern part of the valley mills frequently utilize to advantage logs even smaller.

Much of the present waste in leaving top logs is due, in part, to the improper marking of log lengths. Moreover, where logging is done by contract, a common method in the lower valley, the contractor leaves much small-sized timber in the woods, as by handling only the larger logs he reduces the cost of getting the logs to the river. The contracts should plainly specify that all trees above 16 inches diameter breasthigh that will cut one or more merchantable logs shall be taken unless designated for seed trees. Tops should be utilized to 12 inches where straight and free from branches, or to 14 inches where they contain no more than four or five small branches not over 4 inches in diameter.

To increase the percentage of cottonwood in future stands and gradually eliminate the less valuable species, the latter should be cut whenever possible, even without profit. Actual loss may at times be justified, since it may be considered an investment in restocking the area to cottonwood. As a rule, however, the removal of these "weed trees" will be warranted only where their utilization is possible. For this purpose the erection of cooperage plants on or near logging operations would materially simplify the problem. Such plants could utilize at a profit the larger elm, maple, hackberry, sycamore, and box-elder, as well as much of the cottonwood and gum too small for saw timber. Otherwise, deadening these trees would be the only means of clearing the ground for reproduction. The plants could also utilize a good proportion of the lumber which would ordinarily be left in the

tops. Where the size of logging operations does not warrant setting up such secondary plants, it will often be possible to barge the logs or bolts of the inferior species to hoop mills, excelsior factories, or cooperage plants located in the principal cities along the river. Even though the price received no more than covers the woods and transportation cost, the importance of encouraging cottonwood reproduction will often justify such a disposal.

Charcoal burning and wood distillation is another industry which, if it could be profitably conducted in these bottoms, would aid materially in close utilization. Practically every species could be utilized down to a diameter of 2 or 3 inches, including tops and limbs of felled trees. Maple, elm, sycamore, willow, birch, and hackberry should produce a good grade of charcoal, and be delivered at the pit for $2 per cord. The development of a market for small-sized material would have the additional advantage of making thinnings from young stands of cottonwood practicable. In many instances, however, the utilization of the poorer species will obviously be out of the question. A choice must then be made between leaving them until a market develops or deadening them.

THINNINGS.

The removal of a portion of the trees from a stand not fully mature is termed a thinning. Thinnings, if properly done at the right time, will result in accelerating the growth of the trees left, and at the same time utilize many of the smaller trees which would otherwise die from supression. A thinning will frequently pay for itself. Cottonwood responds in a marked degree to increased light. Its pronounced light requirement is in itself an unmistakable indication that thinnings will be beneficial. It is evident, further, that in cottonwood stands where in the course of natural development the average number of trees per acre falls from 700 to 50 between the ages of 10 and 40 years there must be great loss in growth rate due to competition.

Unfortunately, no example of systematic thinning in young cottonwood stands was found in the present study. On one plot, however, a good many of the trees had been removed in a rather haphazard and unsystematic manner, most of them apparently of the smaller sizes. The beneficial results of this chance opening up were, however, quite apparent. This particular stand was in southeastern Arkansas, and occupied good bottomland soil near the present course of the river. Its age was 17 years. It was stated that rivermen had been in the habit of drawing upon this stand from time to time for ship poles, barge braces, and the like. Cuttings were said to have been made for quite a number of years, although apparently none had been made very recently. Over most of the

area the stand had been opened up too severely, and toward the center many of the dominant trees appeared to have been taken along with the smaller ones. One half-acre plot was laid off, however, in which there was a fairly even distribution of the remaining trees, and from which the smaller or medium-sized trees were the ones chiefly removed. It happened that this small area was properly thinned. Table 7 shows the condition in this half-acre plot in contrast to the average for stands of this age.

TABLE 7.—*Effect of thinning on cottonwood stands.*

	Total number of trees per acre.	Trees per acre over 14 inches diameter, breasthigh.	Average diameter of all trees.	Average diameter of trees above 14 inches diameter, breasthigh.	Stand per acre.
			Inches.	*Inches.*	*Board feet.*
Average plot	215	34	10.5	15.5	4,000
Thinned plot	132	50	12.3	15.9	7,500

In the thinned plot there were approximately 40 per cent fewer trees per acre than in the average plot. Of trees over 14 inches in diameter, on the other hand, there were actually 47 per cent more, and the average diameter of all trees was 17 per cent larger in the thinned than in the average plot.

The results in this one thinned stand are corroborated by measurements of five 15-year-old plots of cottonwood across the river from Helena, Ark., in which was an understory of sycamore and a few other species, all more tolerant than cottonwood, and of the same age as the latter though only one-third the height. It was therefore apparent that the cottonwood started in mixture with the sycamore, but being of more rapid growth soon overtopped it, thereby freeing itself from crowding and side shade. Thus, while not actually thinned, it had passed through a natural stage in some respects closely paralleling artifical thinning. In these five plots the board-foot yield noticeably exceeds the average for the same age stands.

TABLE 8.—*Effect of associate species on form, growth, and yield of cottonwood.*

Age 15 years.	Total number of of trees per acre.	Number of trees per acre over 14 inches diameter breasthigh.	Average diameter of all trees.	Average diameter trees over 12 inches diameter, breast-high.	Yield per acre.
			Inches.	*Inches.*	*Board feet.*
Average of all plots	275	22	9.2	14.9	2,400
Average of 5 plots with sycamore understory	200	27.6	10.4	15.1	3,040

It is fair to assume that artificial thinning would be followed by somewhat similar results.

Economic conditions, such as markets for small material, extent of investment, etc., will govern to a large extent the practicability of thinnings. In the lower Mississippi Valley there is at present little if any demand for the small-sized material which thinnings would yield. Pulp companies, with mills in Indiana and Ohio, have frequently purchased peeled cordwood of small dimensions as far south as Memphis. If such companies find it profitable to establish plants in the lower valley where there are extensive areas covered with young willow and cottonwood, a market might be expected to develop rapidly for the products of thinnings. While in some instances this small material may now be disposed of for fuel, braces, small poles, etc., as a rule it can not be profitably marketed.

There is danger in making thinnings too heavy and so permitting the entrance of objectionable undergrowth. Unless there is an understory of a more tolerant tree, such as green ash, sycamore, hackberry, or silver maple, only very light thinnings are advisable. In such a case the slower growing trees clear the fast-growing cottonwoods of side branches, shade the ground, and prevent the starting of grass and undergrowth.

If the rotation of cottonwood for lumber production may easily be shortened at least five years by thinnings without diminishing the yield per acre, thinnings might in some instances be justified on financial grounds, even when yielding no direct return. The saving of five years' interest on the investment in land and taxes with interest would certainly justify, under some conditions, an investment in thinnings. For example, the cost of maturing a crop of cottonwood in 30 and 35 years would approximate $77.97 and $112.07, respectively. This represents a saving for 30-year-old stands of $34.10. It is not improbable that two thinnings at the ages of 10 and 18 years, respectively, might shorten the rotation, so as to result in practically the same yield at 30 years as it ordinarily requires 35 years to produce. The costs of such thinnings should not exceed $2 and $5 per acre, respectively, which compounded with interest at 7 per cent would represent an outlay of $19 at the end of the 30-year rotation. In other words, the investment in thinnings could be expected to return 7 per cent interest like the rest of the investment, provided it lowers the cost of the crop $19 by shortening the rotation. As a matter of fact, an additional profit of $15.10 would result in this case, represented by the difference between $34.10, the saving in the cost of the crop, and $19, the cost of the thinning. With a larger investment, as in the case of planting, the difference in favor of thinning would be still more pronounced. If the cost of

thinning could be partially or totally met by a market for the material removed, the possibility of increased returns would, of course, be still further improved. Until markets for small stock improve, however, or until more definite conclusions can be made respecting the actual increase in growth due to thinnings, it is doubtful if thinning operations will generally be considered feasible in natural stands of second-growth cottonwood in the South.

ROTATION.

LUMBER.

A rotation of approximately 35 years is sufficient to yield maximum returns from natural stands of pure cottonwood. This is based on present market requirements, and corresponds almost exactly to the age at which a stand has attained its maximum mean annual yield of 840 feet per acre board measure, the trees ranging from 10 to 30 inches in diameter, with an average of 19.7 inches (Table 3).

An average stumpage value of $5 per thousand feet at 35 years is assumed. Below this age, with present merchantable sizes, the stumpage value of cottonwood decreases very rapidly and few stands are now being cut much younger.

Since all forest investments are reckoned at compound interest, the latter necessarily has an important influence upon the length of rotation. This is shown from the following figures, which indicate the necessary increase in stumpage value to warrant extending the rotation beyond 35 years, at which age a stumpage of $5 per thousand is assumed. The investment is reckoned at 7 per cent for a 35-year period. An initial cost of $5 per acre is allowed for establishing the stand by natural reproduction, taxes are assessed at 20 mills on the dollar for a land valuation of $3 per acre, which is assumed to increase $1 each succeeding decade. The sale value or cost of the land is placed at $5 per acre.

Age.	Stumpage.
35	$5.00
40	6.73
45	9.60
50	13.88

Thus, in order to warrant lengthening the rotation from 35 to 40 years, the value of the timber per thousand feet must increase from $5 to $6.73 during this period. This merely means that a stumpage value of $5 per thousand at 35 years will return a net profit equivalent to a stumpage value of $6.73 per thousand at 40 years. At rotations of 45 and 50 years the stumpage value would have to attain $9.60 and

$13.88, respectively. Unless the owner were assured that the larger proportion of high grades cut from stands of these greater ages and consequently larger average dimensions would give the standing timber this large increase in value, he would not be justified in deferring the final cut.

A determination of the rotation necessarily involves some knowledge of the manner in which an increase in the size of logs affects the proportion of different grades that can be cut from a given stand. One or two concrete examples will probably make this clear. For instance, one millman kept a detailed record of the grades sawed from certain logs representing the yield of a heavily stocked stand in northwestern Mississippi cut clear in 1912. This stand was approximately 46 years old, and the logs for the most part ranged from 14 to 30 inches top diameter inside the bark. The following proportion of different grades, based on a two months' cut of nearly half a million feet, is believed to be fairly typical of normally stocked pure stands:

	Per cent.
Boxboards	9
Firsts and seconds	18
No. 1 common	30
No. 2 common	42
No. 3 common	1

In contrast to this is the actual mill tally for a run of unusually large logs from a stand supposed to be at least 90 years old. These high-grade logs ranged from 24 to 48 inches in diameter at the top and cut out approximately the following grades of lumber:

	Per cent.
Boxboards	7
Firsts and seconds	40
No. 1 common	35
No. 2 common	15
No. 3 common	3

This lumber was graded, moreover, in 1901, when grading rules were more rigid than at present. Under present grading rules a large proportion of this material would be put in the next higher grade. In the judgment of some millmen, timber of this quality would run now more nearly as follows:

	Per cent.
Boxboards	15
Firsts and seconds	43
No. 1 common	30
No. 2 common	10
No. 3 common	2

Unfortunately, no records of similar tallies for stands as young as 35 years were found. Several millmen of wide experience, however, gave estimates differing but very little on the probable proportion of grades that could be cut from logs ranging from 14 to 24

inches in diameter, such as could usually be obtained from well-stocked stands of this age. The following figures are believed to be representative of such stands:

	Per cent.
Boxboards	5
Firsts and seconds	18
No. 1 common	30
No. 2 common	47

Prices for various grades will, of course, vary with the locality, season, or year. The following prices, which were fairly typical for the different grades f. o. b. at the mill during the fall of 1912, are used as a basis to determine the relative log values for the several instances cited:

	Per thousand.
Boxboards	$44
Firsts and seconds	27
No. 1 common	21
No. 2 common	16
No. 3 common	12

Using these figures, the actual mill-run values per thousand feet for the instances cited are given in Table 9.

TABLE 9.—*Value of logs of different grades based on actual mill run.*

Age.	Range of logs, diameter inside bark.	Mill-run values per 1,000 feet.	Stumpage.
Years.	*Inches.*		
35	14–24	$20.88	$5.00
46	14–30	21.96	6.08
90	24–48	26.35	10.47

Assuming that logging and milling costs are the same for the three ages cited, it appears that stumpage values will be apt to increase a little more than $1 per thousand between the ages of 35 and 46 years. By comparing the stumpage values given on page 42 it is evident that one can not afford to hold the timber, since the cost increases four times more than the stumpage value. The time for cutting cottonwood stands established to-day must eventually be determined on the basis of future market conditions. From the present indications, however, a maximum of 35 years will be necessary for cottonwood grown for saw timber in natural unthinned stands. In stands established artificially the same yields can probably be obtained in much shorter time, for the regular spacing in such stands enables the young trees to attain in four or five years the dimensions of six or eight year old trees in dense natural thickets. Where thinnings are

possible the rotation can be further shortened. Planted stands which can be thinned once or twice during the rotation might easily reach maturity at least 5 or 6 years earlier than natural stands which have been given no special attention. If improved market conditions make it possible in the future to harvest unmanaged natural cottonwood forests in the Mississippi Valley in 30 years, it would be possible to cut well-managed, planted forests in 25 years or even less.

CORDWOOD.

In average natural stands of cottonwood cordwood can be obtained in about 16 years, with a total yield of approximately 42½ cords per acre, or an annual yield of 2.7 cords. Under particularly favorable conditions of growth the time may be shortened to 13 years. In planted stands the time may be reduced even to 12 years, especially where thinning and cultivation are possible.

Since stands cut for cordwood can be most easily renewed by coppicing, the second rotation should be much shorter than the first because of the more rapid growth of the sprouts.

No stands were found in this country to indicate the exact difference in the length of rotation for coppice and for seedling forest. In South America, where the coppice system is practiced on short rotations, wood of suitable dimensions for saw purposes is grown from cuttings in 10 years, and a second crop equal to the first is obtained by sprout reproduction in 7 years. In the case of natural stands renewed by sprout reproduction the difference between the lengths of the first and second rotations would be much greater than in the case just mentioned, where the first stand was obtained from cuttings, a form of sprout reproduction. Reproduction by coppicing in the Mississippi Valley therefore ought to make possible a second rotation as short as 10 to 12 years.

RETURNS FROM GROWING COTTONWOOD.

The returns from growing cottonwood will depend upon the manner of establishing the stand and the product desired.

LUMBER.

Where a cottonwood stand is to be established by natural reproduction, supplemented by planting, the following costs per acre may be taken as conservative:

Site preparation	$2.50
Seed trees	1.25
Planting one-third the area	1.25
Total	5.00

Where the stand is to be established wholly by planting the costs will be:

Preparation of the ground	$2.50
Cost of stock (8 by 8 feet)	1.00
Cost of planting	2.50
Filling in blanks	1.00
Total	7.00

The cost of the land will vary widely under different conditions, but at present $5 per acre will be the average price of unprotected land unsuitable for farming. Such lands are usually valued for taxation purposes at only $1 to $3, and are seldom taxed more than two cents on the dollar. Some allowance for increased taxes in the future should, however, be made. The present land valuation for tax purposes is therefore placed at $3, and an increase of $1 per acre allowed for each succeeding decade.

It is a fair assumption that a stand established by natural reproduction, supplemented by planting one-third of the area, will yield at least three-fourths as much as the fully stocked stands shown in Table 3. On the basis of these figures such a stand would, if the stumpage is worth $5 per thousand board feet, return 7 per cent on the investment, with a rotation of about 35 years.

A planted stand, fully stocked, even though the cost of establishing it may be higher than in the case of a stand secured by natural reproduction, should return about 7.3 per cent, because of its greater yield per acre.

While on the whole at least 6 or 7 per cent can be expected from growing cottonwood, the profitableness of the undertaking must be determined for each particular case by a careful study of local conditions.

CORDWOOD.

The present low stumpage value of cordwood makes it a questionable policy to sacrifice thrifty young cottonwood brakes for this use. Such stands, if established in the same manner and at the same cost as described for saw timber, will show a return of scarcely 6 per cent. This requires a fully stocked stand over the entire area, which can scarcely be secured except by planting. With only three-fourths of a normal yield per acre, as figured for saw timber, the investment would not net more than 4 per cent. If natural reproduction, supplemented by planting, would result in a fully stocked stand, the returns may be increased to 5 per cent.

To make the growing of cottonwood for pulp as profitable as for saw timber, the stumpage must bring from 80 to 90 cents per cord.

The possibility of pulp companies growing cottonwood near their plants is of special interest. It does not seem unlikely that the much higher stumpage value of pulp wood located within hauling or short shipping distance of such mills may even justify the use of fairly good farm land for this purpose. For example, if a company, by cultivation, thinning, etc., could raise a crop of cottonwood in 12 years, with a yield of 47 cords per acre, worth $2 per cord on the stump, it might be feasible to invest as much as $50 per acre in land, provided it were rich, moist, but well-drained bottom land naturally adapted to the tree. Land as expensive as this would be already cleared. It could be put into condition for planting by plowing, etc., for $2 per acre. Assuming that 6 per cent return would satisfy a company growing its own pulpwood, the following outlay per acre would be adequate:[1]

Interest on cost of land at $50, 12 years, at 6 per cent	$50.61
Initial outlay (stock $1.50, planting $2.50, soil preparation, $2), $6, 12 years, at 6 per cent	12.07
Taxes (2 per cent on one-half value), 50 cents per year, 12 years, at 6 per cent	8.43
Thinning at eight years, $2, four years, at 6 per cent	2.52
Cultivation, $4 per year first two years	15.64
	89.27

The gross returns would be represented by 47 cords of pulp wood at $2 per cord, or $94.

The crop would be renewed by stump sprouts at practically no cost, except cutting back all but the best sprout on each stump during the summer after felling. This should not exceed $2 per acre. Cultivation would be necessary, since the renewed stand would be only half as dense. Because of the more branchy growth pruning would doubtless be needed after 3 or 4 years, but no thinning would be required. A 10-year rotation would probably be ample for this coppice growth, so that the new crop could easily return 8 per cent, as shown by the following costs and returns per acre:

Interest on cost of land, at $50, 10 years at 8 per cent	$57.95
Cutting off sprouts, $2, 10 years, at 8 per cent	4.32
Taxes (2 per cent on one-half valuation), 50 cents, 10 years at 8 per cent	7.24
Cultivation, $4 per year for first two years at 8 per cent	16.63
Pruning when 4 years old, $5 at 8 per cent	7.93
Total	94.07
Gross returns, 47 cords pulp wood at $2	94.00

[1] No filling in of blanks will be necessary because of the close planting and thorough prepartion of the ground.

PLANTING.

ADVISABILITY.

Wherever fully stocked stands can be secured by natural reproduction no planting need be done. Where seed trees of cottonwood are wanting, on low-lying areas where water stands late in the spring, and on areas where young seedlings might be choked out by vines, briers, or low underbrush, it will be necessary to supplement natural reproduction with planting. Without planting, many portions of the logged-off areas would be only indifferently restocked, while in some places reproduction would be entirely lacking.

Planting, however, is not limited to the restocking of cut-over bottom lands. A tree of such rapid growth and value as cottonwood will no doubt be introduced into localities where it is not now found naturally. The present local occurrence of cottonwood does not necessarily coincide with the areas where it might be expected to make good growth. The fact that this species is seldom found growing naturally far from streams or moist bottom lands is the result of the failure of its seed to germinate satisfactorily on any but moist exposed mineral soils, such as are provided by the deposits from spring floods. This difficulty, however, is avoided by planting young trees. When the roots of the planted stock penetrate to a moist subsoil the tree displays its usual rapid development.

Carolina poplar and Norway poplar are extensively advertised by nurserymen as superior to the common cottonwood for rapid growth in forest plantations. The three trees are all closely related. Differences in leaf and growth characteristics are often urged as grounds for considering Carolina poplar and cottonwood as distinct species. Carolina poplar itself, however, shows widely varying characteristics in different sections of the country, and often can not be distinguished from cottonwood. The differences between Norway poplar and cottonwood are equally vague. Both Norway and Carolina poplar are male trees propagated entirely from cuttings, and it is believed that both are derived from staminate trees of our common cottonwood. It has already been pointed out that cottonwood has been commonly planted in Europe, where certain nurserymen claim to have developed exceptionally rapid growers. Possibly our Norway poplar may have originated in some such way, or it may have been taken originally from some of these rapid-growing European forms. It is not at all certain, however, whether it really exceeds our native cottonwood or the Carolina poplar in growth. Indications are that in the north cuttings from thrifty Carolina or Norway poplar may develop more rapidly than cottonwood. In fact, it is generally believed that the male trees are more vigorous growers than the female. Another merit claimed for Norway poplar in com-

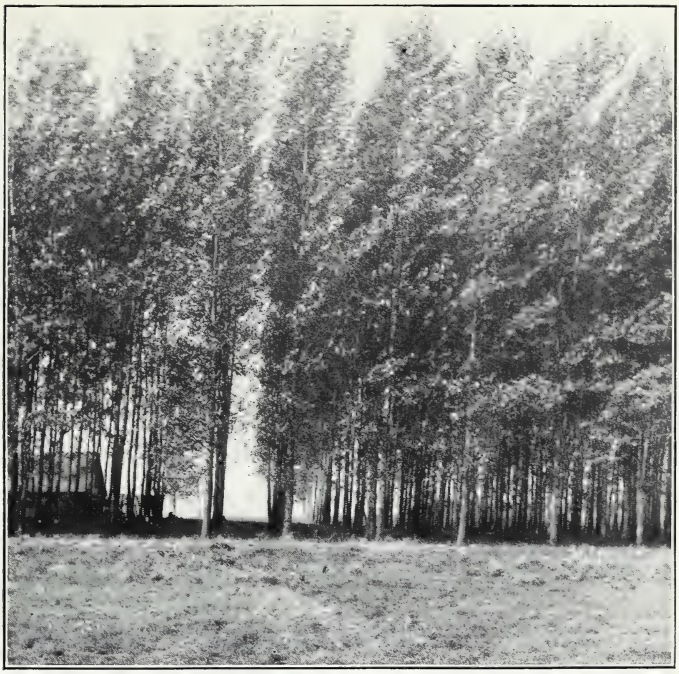

FIG. 1.—COTTONWOOD SHELTERBELT 10 YEARS OLD, SOUTHERN MINNESOTA.

FIG. 2.—INTERIOR OF FARM GROVE OF COTTONWOOD 12 YEARS OLD, SOUTHERN MINNESOTA.

FIG. 1.—GERMAN PLANTATION OF COTTONWOOD 5 YEARS OLD, SHOWING WIDE SPACING, 12 FEET BY 15 FEET, AND RESULT OF HEAVY PRUNING.

FIG. 2.—AMERICAN PLANTATION OF COTTONWOOD 4 YEARS OLD, CLOSELY SPACED, 4.5 FEET BY 9 FEET, AND IN NEED OF THINNING.

parison with other poplars is that it forms a better shaped stem, freer of side branches. Such conclusions are based on a comparatively small number of plantations in southern Minnesota, which hardly afford sufficient grounds for recommending this tree in preference to the better known cottonwood or the Carolina poplar.

PLANTING SITES.

Moderately well-drained, permeable bottom lands afford the best planting sites. The soil need not be rich or loamy. Very sandy land will be suitable if the water table is within from 12 to 15 feet of the surface. Even upland sites may sometimes be suitable, provided the soil is not too shallow and rainfall is abundant and well distributed. Suitable upland sites, however, are apt to be well adapted for farming.

COMMERCIAL PLANTING.

The cottonwood lumber industry is almost exclusively confined to the Mississippi Valley, where maximum returns can be obtained on a 35-year rotation, or in the central and southern sections perhaps on as short a rotation as 25 to 30 years. Even in the north, where the growth of cottonwood is comparatively slow, the better market for small sizes will make it possible to produce saw timber in 35 to 40 years. For the present, however, planting for lumber should probably be restricted to the central region.

The Northeastern and Central States offer another opportunity for realizing profitable returns from cottonwood plantations located close to pulp mills. Several pulp-manufacturing companies have already started plantations of cottonwood.

Black cottonwood (*Populus trichocarpa* Torr and Gr.), which is very similar to the cottonwood of the Mississippi Valley, has been planted to some extent for pulpwood in western Oregon and Washington. The success already attained with this species emphasizes the possibilities of our eastern cottonwood in the region. The common cottonwood should do well in the Pacific Coast States, where the markets for pulpwood and box material should afford a ready outlet for the products of plantations. It is not certain, however, that *Populus deltoides* will excel in any respect the native *Populus trichocarpa.*

PLANTING FOR WINDBREAKS.

Cottonwood plantations are often warranted where, as in Iowa, Minnesota, the Dakotas, Kansas, and Nebraska, timber for lumber, posts, and fuel is scarce. Plantations of cottonwood made by the pioneers in those States from 30 to 50 years ago, often on dry upland sites, have in many instances been sawed up into rough lumber at

a decided profit. Commercial planting in this region, however, should be restricted to bottom lands, or, in the case of windbreaks, to good farm land. (See Pl. V, fig. 1.)

The possibility of combining timber growing with windbreak planting opens up an important field for cottonwood in the Middle West on farm lands too valuable to permit of timber production for its own sake. One of the chief requisites in a windbreak tree is rapid height growth. Cottonwood meets the requirement better than any other species. It is adapted to any good, moist situation, such as river bottoms, or even typical farm land of the rolling uplands of the eastern portion of the region, where rainfall is comparatively heavy. On dry situations, where long droughts are common, a less exacting tree is better.

There is, however, a serious objection to cottonwood for windbreaks, due to the sapping effect of its roots upon adjoining crops. It is generally considered more injurious in this respect than any other tree used for windbreaks in this region, and many farmers are cutting down groves or belts of cottonwood with no intention of replanting it. As a matter of fact, however, actual measurements made by the Forest Service show conclusively that in comparison to its height cottonwood is the least injurious of any species commonly used.[1]

The sapping effect of cottonwood, as of any other tree used for windbreaks in the Middle West, is almost always more than offset by the increased crop yield on the fields protected. Windbreaks in this region will usually more than repay the rental for the actual area of valuable farm land which they occupy without even taking into account the direct financial returns from marketing the wood product.

Since the tree's foliage is rather open, cottonwood windbreaks should be underplanted with a shade-enduring species either as soon as the stand begins to open up or else at the outset. For this purpose any one of the following trees will do: white or green ash, red oak, box-elder, and silver maple. Another method of overcoming this difficulty would be to plant only two or three rows of cottonwood the first year, and to plant additional rows on the side most exposed to the sunlight as soon as the original trees show a tendency to become open. Two hundred and forty feet has been recommended as the most suitable width for a windbreak belt of cottonwood in this region.

PREPARATION OF SITE.

Planting without a thorough preparation of the site is inadvisable. On freshly cut-over land the preparation should be practically the same as for natural reproduction. Full sunlight is equally indis-

[1] Forest Service Bulletin 86, "Windbreaks."

pensable both for natural grown and planted cottonwood. Planting on heavy sod is never advisable. If plantations are to be established on improved farm land for windbreaks, it will be of advantage to plow and harrow the ground. Plowing will cost not more than $2 per acre. The higher stumpage values of cottonwood on the prairie farms of the Central West, from $10 to $12 per thousand feet, will, moreover, warrant this more intensive preparation.

On cut-over bottoms cultivation of the ground preparatory to planting is usually not justified from a financial standpoint, nor is it essential, since the amount of moisture is so much greater and rich alluvial sediment is deposited every year by spring overflows. On bottom lands cleared for farming, however, cultivation is as advantageous as on the uplands.

There is another type of bottom land which, though not growing up to trees or underbrush, is nevertheless so completely covered with tall, thick, dense-growing weeds, principally horseweed in the North and indigo plant and cocklebur farther south, that planting without first preparing the ground is out of the question. Abandoned fields and old filled-in river beds and lake bottoms are typical of this kind of land. These weeds on such land are sometimes 10 or more feet high. They can not readily be plowed under unless they are first broken down so as to lie with the furrows. This can be done by hitching a team to each end of a 30-foot log and rolling it over the weeds, breaking them off close to the ground. This must be done in the fall, when the stems are stiff and dry and snap off easily. The cost of clearing and plowing such land should rarely exceed $2.50 per acre.

The thoroughness with which the ground is to be prepared must depend, of course, on the returns to be expected. As a rule, these can be placed at 7 per cent. Assuming a rotation of 35 years, with a yield of 29,400 feet board measure, worth $5 per thousand on the stump, the total gross returns would be $147 per acre. The interest for 35 years on an assumed land value of $5 amounts to $48.38; taxes based on a valuation of $3 now and an increasing value of $1 for each successive 10-year period will represent an investment of $10.31 at a tax rate of 2 cents on the dollar. Assuming the initial cost of stock and planting at $4 per acre, or $42.71 in 35 years, the total investment with interest at 7 per cent less the cost of preparation will be $101.40. This leaves $45.60 available for the cost of preparation, including interest. In other words, approximately $4.25 per acre can safely be invested in preparing the site. If it is unnecessary to expend the whole of this, the net annual return will be proportionately increased. On the other hand, if this amount is insufficient to give adequate preparation, the other items of expense must be reduced, or else the owner will not receive his 7 per cent.

METHODS OF PLANTING.

In planting cottonwood either cuttings or wild-grown seedlings have been largely used. Although growing seedlings in nursery beds and transplanting them out when they are a year old is the method usually recommended for most trees, yet in the case of cottonwood, because of the difficulty of handling the seed and the simplicity of the first two methods mentioned, nursery practice is less practicable. Reforestation by direct seeding over the area to be stocked will, as a rule, also be impracticable.

WILD SEEDLINGS.

An abundance of 1-year-old wild seedlings can in most years be found in dense thickets on overflow lands along the Mississippi River and its tributaries. If these are collected, only the best should be straggling root system is decided contrast to the stocky, fleshy, coming on coarse sand. The latter are very apt to have a rather long, straggling root system in decided contrast to the stocky, fleshy, compact roots characteristic of trees growing in rich moist soil. Not only will this latter stock prove more vigorous, but it will be much easier to handle. It should not, however, be transplanted to exceptionally dry sites. One-year-old trees are usually the best, except when they have to compete with weeds and grass. Older trees are apt to be so large that they are expensive to handle. The wild seedlings should be taken up before they have begun to grow in the spring. If possible, they should be collected after a heavy rain, when they can be pulled out without injury to the roots. They may be dug up with a spade, but a better method is to turn the surface soil with a plow. Stock can sometimes be collected in this manner as cheaply as 50 cents per thousand, and should seldom cost $1. Wild seedlings can generally be purchased from nurserymen or collectors for from $1.50 to $2.50 per thousand. It is advisable in purchasing collected seedlings to make sure they come from a region of similar climatic conditions.

NURSERY SEEDLINGS.

Nursery-grown seedlings are seldom used in the establishment of cottonwood plantations. On dry sites, however, the superiority of seedlings over plain cuttings is unquestioned. Although nursery practice with cottonwood in this country is still in its infancy, a fairly good stand of young seedlings may be obtained in nursery beds at a very low cost. In fact, where rooted stock is essential and wild seedlings are not available, nursery seedlings can be produced at less expense than rooted cuttings.

Cottonwood matures its seed in the south as early as the last of April or first of May, while in the latitude of Minnesota seed may

often be obtained up to the second week in June. Abundant seed is produced annually. The seed should be collected just before the pods or capsules begin to open, although large quantities of it could easily be obtained later in protected places on the ground. Seed collected from the ground, however, is apt to be mixed with other material such as leaf litter or even with seeds of other species, particularly of willow, which also mature early. Furthermore, ground-collected seed is obviously not so fresh as that in the unopened capsules; this, because of the short vitality of cottonwood seed, is a disadvantage. In the case of large open-grown trees, the catkins may easily be picked from the tree by a man with a ladder. Where logging operations are in progress at this season seed can be obtained from felled trees at a very low cost. It is also frequently possible to obtain plenty of green catkins of good quality which have been blown off the trees by heavy winds just before opening. As a rule, however, the picked seeds are more dependable.

The green "seed balls" should be kept well aerated. If stacked in large piles or kept in closed receptacles there is danger of their becoming heated and possibly losing their vitality. They should, therefore, be spread out to dry as soon as collected, and when they begin to open should be covered over with strips of paper to prevent the cottony seed from escaping into the air. As soon as the capsules are wide open the seeds are ready for sowing. The vitality of the seed lasts for only a week or two at the most.

The nursery bed may be prepared in the same manner as for any other broadleaf species. The soil should be deep, moist, and permeable. It should be well worked to the depth of about a foot. Sandy soils should be enriched and well mixed with manure. The surface of the beds, after being thoroughly worked, should be rolled smooth.

The seed balls may be spread out on the surface of the prepared nursery bed as soon as they have been collected, and thus allowed to dry out in the sun until the pods are opened sufficiently to shed the seed. Best results can be obtained by collecting small branches bearing a good supply of seed catkins and laying them on the beds with the catkins still on them. As soon as the seed balls open the seed can readily be shaken out over the surface of the bed, after which it should be soaked down and lightly covered with a sprinkling of sand. After the pods have begun to open it may be necessary to keep the beds covered with strips of heavy paper in order to prevent the escape of the "cotton." The seed must be shaken out over the bed on a very calm day, or else beneath the paper cover.

If the seed balls have dried previous to sowing, the seed should be spread as evenly as possible over the surface of the bed until it is entirely covered with a very thin layer of cotton. Over this dry

soil should be evenly sifted until the cotton is just hidden from view. The bed should then be thoroughly saturated with a light spray of water. The surface moisture can be preserved by covering the bed as soon as sown with paper strips, which, however, should be removed as soon as the seedlings begin to appear. The seed beds should be watered from time to time as necessary.

Still another method which has been reported as successful is carefully to mix the seeds, which have been allowed to open in paper bags, with moist soil, which prevents their blowing away, and sow the mixture of soil and seeds evenly over the bed and cover very lightly. Care must be exercised not to cover the seeds too deep—not over an eighth of an inch, or barely enough to hide them from view.

Except when the branches of green catkins are spread over the bed, it is well to drench the soil thoroughly before sowing the seed. It is of great importance not to let the surface become dry before the seedlings have developed fairly deep roots.

The seed may be either broadcasted or sown in drills or rows. When the seed capsules are allowed to open on the bed, however, the latter method will be impracticable. Broadcasting is apt to result in overcrowding, and so in spindling weak stock. In broadcasting, therefore, the seed should be sown sparingly, only a very thin layer of cotton being spread over the surface of the bed. If the stand is too dense it should be thinned. Fifteen to 20 trees per square foot is a sufficiently dense stand at the end of the first growing season. If the seed is sown in drills the beds can be more easily weeded and cultivated. Broadcasting, on the other hand, permits fewer weeds to start. The trees in the rows have plenty of side room for development, and are therefore more stocky and vigorous. On heavy soils, where alternate freezing and thawing during the winter is likely to injure a good many of the seedlings by gradually lifting them from the ground, the rows of trees can be better protected than the broadcasted beds by spreading a thick covering of straw over the ground between the rows. Thinning may often be necessary even in drill-sown beds, for the seedlings should not stand closer than 2 inches in the row, which will allow 18 trees per square foot, with 4-inch intervals between the rows.

By fall nursery-grown seedlings should reach a height of at least 2 feet. They will be ready for taking up and planting early in the spring as soon as the frost is out of the ground, or, where fall planting is practicable, as soon as growth ceases in the fall.

TREATMENT OF SEEDLINGS BEFORE PLANTING.

Methods of handling seedling stock preliminary to planting are the same for both nursery-grown and wild-grown trees. Above all, the roots should not be allowed to dry out before planting. The

seedlings may be bundled together in bunches of fifty or a hundred and the roots covered with wet burlap or wet sphagnum moss. The tap-roots of vigorous seedlings may often be too long to handle easily. In such cases they should be cut with a sharp knife 12 inches or less below the root collar. If they can not be planted for several days they should be "heeled in" in a trench deep enough to bury the roots and part of the stems. The trench should run east and west, with its south bank somewhat sloping. The bundles of trees should then be placed side by side in the trench on its sloping side, their tops toward the south, and their roots and stems covered 2 or 3 inches deep with fresh earth dug from the opposite side of the trench. A second layer of trees should then be put in and covered as before, and the process repeated until all the trees have been heeled in.

CUTTINGS.

Cuttings are used in establishing most cottonwood plantations. The quality of cuttings depends very largely on the character of the parent stock, since a cutting will display essentially the same growth characteristics. Cuttings for planting in the central or southern part of the valley should be obtained from that region rather than from the far north. Cuttings from trees in regions of low rainfall, such as the valley bottoms of Nebraska or Kansas, would not be as suitable for planting in the Ohio Valley region as stock obtained from the central Mississippi Valley. Again, if planting is to be done on good bottomland soils, the cuttings should not come from ornamental trees growing on comparatively upland situations. Particularly where cutting stock is purchased from commercial nurseries, the planter should make sure that the parent trees are of the right kind.

The best cuttings are obtained from vigorous growing trees, preferably from the branches near the top. It may sometimes be possible to obtain cuttings of good quality from trees which are removed in a thinning, provided, of course, only the more thrifty intermediate trees are used for the purpose. Cuttings taken from the current year's growth are superior to those from older parts of the branch. Two-year-old wood, however, will usually be found entirely satisfactory, but wood older than this should not be used. Root cuttings are vigorous, but are difficult to obtain.

A convenient length for cuttings is about 18 inches, although under certain conditions the length may range from 10 to 36 inches. They should be made immediately after the tree is felled, in order to prevent the drying out of the twigs. In making them it is preferable to cut the twig off at a slant of about 45° with a thin-bladed, sharp knife. In this way one avoids crushing the stem or loosening the bark. Care should be exercised that none of the buds from which

the young sprouts later take their origin are rubbed off or injured. Liability to such injury can be largely reduced by tying the cuttings into bundles of any convenient size, which will also facilitate their counting. The tops should all be laid in the same direction, in order to facilitate planting. Although cuttings will sometimes grow when planted top downward, their growth in this position is not thrifty.

TREATMENT BEFORE PLANTING.

Cuttings are set out either plain or rooted. Plain cuttings may be set out either fresh or callused. A fresh cutting, however, is not so well equipped to establish itself in a slightly unfavorable new environment as is a young seedling whose roots can at once absorb nourishment. The cutting must first heal over the cut surfaces, which it does by forming a callus. It is then prepared to send out new roots, usually from this callused surface, but often also from points along the stem. During this period of adaptation and root formation suitable moisture conditions are essential. The soil should be well drained, permeable, and moderately warm. Weeds, grass, or brush should be kept down.

On the more unfavorable sites it is advisable to use callused cuttings, or even rooted stock. Callused cuttings have the cut surface healed over prior to planting, and are produced by burying bundles of cuttings in moist sand. If they are made in the fall and buried outdoors, the sand should cover them to a depth of about 2 feet to keep them moist and protect them from freezing. The surface soil should be protected with a covering of straw or leaves. Another good method consists of packing the bundles in boxes of moist sand which are stored in a cool room or cellar not subject to freezing. Stock kept in this way over winter should be in prime condition for early spring planting. If the cuttings are not prepared till spring, they should not be buried so deeply. At this season of the year the formation of the callus can be more quickly induced by selecting a spot with a southern exposure and a mellow, porous, and moist soil. The cuttings, bundled as before, should be buried with the large end within an inch or two of the surface. After 2 or 3 weeks, provided the ground is kept uniformly moist, the warmth of the soil will stimulate the healing of the cut surface. Where cuttings are set in nursery rows for the summer this treatment will considerably increase the percentage surviving at the end of the season. In burying the cuttings the buds must not be damaged.

On rather dry surface soils or where the young stock must grow rapidly to keep above weeds it is unwise to use any but rooted stock. One-year-old seedlings meet the requirement, but rooted cuttings will also prove valuable and may sometimes be superior to seedlings because of greater height. These are merely cuttings that have been

temporarily set in nursery beds, where they have developed roots and tops. The soil in the nursery should, if possible, be permeable and somewhat sandy. The ground should be prepared in the same manner as for a seed bed and the cuttings set to a depth of about 9 inches. If planted too deeply it will be difficult to take them up without injury to the roots, many of which form at the callused surface. In developing rooted cuttings, therefore, comparatively short sections are preferable, about 10 to 12 inches long. Not over 2 or 3 inches of the stem will protrude above the ground surface, but on this section there should be at least one good bud from which the new growth may spring.

The fresh or plain cuttings may be set in the nursery by preparing holes with a small stick or an iron bar, the holes to be slightly smaller in diameter than the cuttings themselves. If the soil is sufficiently soft and light, holes will not be necessary. If the cuttings are set at an angle with the ground, the soil may be more firmly packed by the foot. With this method there is danger that the roots will be cut when the stock is taken up from the nursery. A spacing of about 6 inches in the row and 1 foot between the rows will give the cuttings plenty of room for vigorous development and at the same time allow of hand cultivation. If there is plenty of available ground for the beds, a spacing of 2½ feet between the rows will be preferable, since it permits the use of a one-horse cultivator.

Since the growth of cuttings in the nursery is usually vigorous, it will scarcely ever be advisable to leave them there more than one summer, lest the root system becomes too extensive to handle easily in planting. A comparatively small, stocky, but vigorous root system develops where the soil of the nursery site is kept fairly moist throughout the growing season. The stock should be watered during drought. The cuttings may be taken up and planted on the permanent site the following spring, or, in the southern part of the valley, as soon as growth ceases in the fall, when they should be from 3 to 6 feet high.

SEED.

The difficulties of sowing cottonwood seed in the field render this method of little practical value. The light, buoyant, cottony seeds make it almost impossible to keep them where sown except during a dead calm. Even after sowing a large proportion of the seed will be blown away unless held down by the moist ground or by rain.

Seedspot sowing consists of placing several seeds at regularly spaced intervals rather than sowing over the entire area. So far as known this method has never been tried, and, like broadcast sowing, it is considered of little practical value. The only possibility of its use with cottonwood would be on wet situations, where a slight cover-

ing of soil would insure keeping the seed moist. The labor, however, would not be materially less than setting cuttings, while the chance of failure would be much greater.

COMPARATIVE MERITS OF DIFFERENT METHODS.

The use of fresh cuttings has the one advantage of cheapness. Such stock can easily be prepared for 75 cents per thousand. It is, however, the least thrifty of all planting stock. Its chief use is for planting on cultivated soil, as for farm woodlots or windbreaks, or on low sand bars with the water table within a few feet of the surface. Callused cuttings are slightly more expensive than fresh ones. The best quality of callused cuttings, made in the fall and stored in sand over winter, should not cost over $1 to $1.50 per thousand. They should do well on moderately dry soils or where there are some weeds, but not too many. Callused cuttings planted during the winter or early spring in the southern Mississippi bottoms will usually be rooted and will have started top growth before being covered by the spring floods. For this reason floods will not injure them greatly. Under such conditions fresh cuttings might not be sufficiently established to resist injury, and if completely submerged for a long period would probably be killed. Sometimes untrimmed branches, 4 to 5 feet long, are used as cuttings in order that the water may not entirely cover them.

For general planting in the overflow bottoms rooted stock will usually be superior to plain cuttings. It is better able to withstand adverse conditions, and even if killed back by rodents or by fire it will be likely to send up new shoots from below the injured portion. Wild seedlings will generally be employed because of their cheapness and availability. The cost of collecting them should seldom exceed $1 to $1.50 per thousand, or the same as for callused cuttings. Such stock is but little injured by complete submergence, remaining in good condition for weeks under water. They are ready to start height growth as soon as planted, which is a valuable characteristic in situations where weeds are likely to spring up.

Nursery seedlings have all the advantages of wild stock, except cheapness. A conservative estimate of the cost of propagating nursery stock is from $2 to $3 a thousand.

Cost is the principal objection to rooted cuttings. Their value for planting lies in their greater height than one-year-old seedlings combined with a vigorous, bushy root system. They are especially adapted to dry situations or where they are likely to come into competition with weeds. Their cost should not exceed $4 to $5 per thousand, and if grown on a large scale—as many as 50,000 to 100,000 at a time—it ought to be considerably less.

FIELD PRACTICE.

METHODS.

Cottonwood seedlings possess a long, thick taproot, with a few short, fibrous laterals. Methods of field planting will differ little with seedlings or cuttings. One of the best tools for setting either kind of stock is a long, narrow-bladed spade, with a sharp cutting edge, which can be inserted at least 12 inches into the ground. The blade need not be over 4 to 6 inches wide, but should have a foot extension for forcing it more easily into the ground, and a cross-bar handle to turn in making the hole. The soil can readily be filled in about the plant by forcing the earth from the outside by several insertions of the spade and finally firmed down about the plant with the foot. To facilitate the work a boy should insert the tree in the opening and hold it in place, while a man firms the earth about it. The boy also carries the basket of cuttings or seedlings. Seedlings should be set slightly lower than they stood in the nursery bed. Cuttings should be inserted about a foot deep. In cultivated soil, where short cuttings are practicable, they should be buried for their whole length, with the exception of 3 or 4 inches of top bearing the bud, and may be set at an angle of nearly 45° with the surface in order to facilitate packing the earth about them.

A plain pointed iron bar will often serve for planting cuttings. This may be improved by attaching a cross handle and foot bar similar to those described for the spade. A very satisfactory planting tool of this character can be made of iron gas pipe, with the lower end brought to a sharp point of specially hard temper.

COST.

By working 10 hours a day a man and boy should be able, after a little experience, to set out 1½ acres of seedlings or 2 acres of cuttings per day, which would amount to from 1,020 to 1,360 trees, if spaced 8 feet apart each way. Proper alignment of the rows can be gained by using flags or stakes, by which one man in each crew can line himself in. Assuming that two men plant an acre and a half per day, and allowing a wage of $2 for the man and $1.25 a day for his assistant, the total cost of planting should not exceed $2.50 per acre.

In the case of cuttings, which are easier to handle, this cost may fall below $2 per acre. If a closer spacing is adopted the cost will be proportionately increased.

Some rather large planting operations with cottonwood have been reported in which the total cost per acre, including cost of stock, preparation of site, and planting, with a spacing of 6 by 6 feet, was only $5 a thousand for seedlings and $3 for cuttings. The planting stock in this case was collected by the company in the vicinity of the planting.

TIME TO PLANT.

Spring planting is recommended. In the Northern States, in particular, fall or winter planting is likely to meet with poor success. The alternate freezing and thawing of the ground during the winter will often lift the plants entirely out of the ground. This applies equally to cuttings and seedlings. On light, sandy soil, however, this danger is comparatively small. In the south of the valley the danger of frost heaving is slight, and if planting is not done on very heavy soils there are advantages in planting during late fall or winter. Seedlings planted early in the fall will recover from any root injuries and become well established before spring. In fact, stock planted early in the fall will continue root activity well into the winter, and therefore will begin growth early in the spring. This will enable it to withstand better the spring overflow, which in the South is apt to occur within 4 or 5 weeks after vegetation begins. Furthermore, autumn planting is better in localities subject to prolonged drought in the spring. In general, however, fall planting, at least for the present, should be restricted to rooted stock, as it is still uncertain how well plain cuttings would withstand long exposure throughout the winter and overflow in late spring.

PURE VERSUS MIXED PLANTING.

Cottonwood may be planted either pure or in mixture with other species. An advantage of pure plantations consists in the greater simplicity of field planting and its consequent lower cost, especially since cottonwood stock is usually cheaper than that of any other hardwood tree that might be used in mixture with it. Pure plantations yield a larger quantity of solid wood on a short rotation.

The advantages which may possibly result from mixed plantations are a possible increase in the board-foot yield; an improvement in the quality of the timber, due to clearing cottonwood of its branches; and in shading the ground. Mixed planting is particularly of advantage in the establishment of windbreaks, for which cottonwood, as it matures, becomes too open to be thoroughly effective.

The associate species ordinarily would have no value, except possibly for cordwood. It would act chiefly as a "filler" to improve the quantity or quality of the cottonwood. Any of the following species would make suitable fillers: Silver maple (*Acer saccharinum* Linn.), boxelder (*Acer negundo* Linn.), sycamore (*Platanus occidentalis* Linn.), white ash (*Fraxinus americana* Linn.), and green ash (*Fraxinus pennsylvanica* Marsh). Probably the silver maple will be the most suitable species. One-year-old maple seedlings can be purchased from dealers for $2 to $3 a thousand. If a filler is

used, it should be planted with the cottonwood in the proportion of 3 to 1, with a row of the fillers alternating with a row in which every other tree is a cottonwood.

SPACING.

Where pulpwood production on a short rotation is desired, an initial spacing of 8 by 8 feet will give the best results. This will serve to clear the branches early and will allow one thinning where it may be financially justifiable.

For timber a spacing of 10 by 10 feet on the richest bottom lands is not too wide for the best growth of cottonwood. Thinning operations with such spacing could be deferred for a long time, as they would be of little advantage before the age of 12 to 15 years.

The readiness with which cottonwood thins itself naturally makes wider spacing than this inadvisable, and on average soils a spacing of 9 by 9 feet may be best. On comparatively dry soils a spacing as close even as 6 by 6 or 7 by 7 feet may sometimes be justified.

A general spacing of 6 by 6 feet, in which the cottonwood is set 12 feet apart each way and the intermediate spots are planted with a filler, is probably the best for mixed plantations. In such spacing every other row would contain only trees of the species used as a filler, while the intermediate rows would consist of cottonwood alternating with the filler. This would give a stand of about 300 cottonwoods to the acre, which is a normally dense stand between the ages of 14 and 15 years. Therefore, no thinnings would be needed before the plantation had become from 15 to 20 years old, when much of the material removed would probably be marketable for pulpwood, excelsior, etc. If the original planting were 8 by 8 feet, with the cottonwoods 16 by 16, the stand would not become much overcrowded during a rotation of 25 years. In the latter case, however, less provision would be made for trees injured or killed, and the timber would probably be less perfectly cleared of its side branches

SUMMARY.

Cottonwood is perhaps the most important tree in the Mississippi Valley, and may be expected to play a large part in the future production of lumber, veneer, and pulp wood. It grows rapidly, and can be cut for pulp wood when 15 years old and for timber and veneer in 35 years. To the owner of unprotected bottom land, lumber and pulp companies, therefore, it should appeal as a profitable tree to grow in the region, especially on the extensive areas outside the river levees.

Cottonwood does not renew itself on cut-over land unless special care is taken in logging. A direct effort must be made therefore to secure restocking on the ground after cutting, either naturally or by

planting. Clear cutting and eradication of undergrowth and useless trees is necessary in any case. To insure natural reproduction seed trees must be left and the soil prepared for the seed. On situations unfavorable to natural reproduction cottonwood must be planted. Planting, in fact, will probably be necessary to supplement natural reproduction over large portions of nearly every extensive bottom-land tract. Artificial reproduction is but little more costly than natural, and since under it results are much more certain, it may often be advisable to employ it exclusively.

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